Energy Research and Development Division
FINAL PROJECT REPORT

APPENDIX G:
THE MESA FIELD GUIDE

Mapping Episodic Stream Activity

Prepared for: California Energy Commission
Prepared by: California State University, Fresno
California Department of Fish and Wildlife

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Readers with recommendations, comments, or questions about this report may contact the authors at the addresses on the preceding page. Contact R. Brady regarding the report in general. Contact K. Vyverberg regarding the El Paso Fan, Lucerne Valley Fan, or Palo Verde Mesa stream delineation case studies in Chapter 5.

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ABSTRACT

Utility-scale, renewable energy projects are being planned and developed in dryland regions of California, mostly on public lands where episodic streams – streams having only periodic flow – are dominant. Developing these facilities can radically and detrimentally alter the landscape, drainage patterns, and natural habitat dependent on these streams.

Even though episodic streams can be dry throughout most of the year, they have high biodiversity. Habitat values are protected by existing environmental laws, and must be managed and protected whenever possible. To comply with the California Fish and Game Code, the California Department of Fish and Wildlife must be notified and consulted with when there is a potential for project-related impacts to streams. The notification requires an accurate description of the natural streams at the site, which implicitly includes an assessment of the type and recency of stream-related processes. However, such analysis and reporting has been problematic because no consistent protocol or guidance exists for project developers to use in place of methods and tools developed for other purposes. Consequently, many projects under-report the numbers of streams present. This has caused long and expensive delays in the permitting process; infrastructure has been damaged by flooding; and habitat that could have been conserved has been detrimentally impacted or destroyed.

To rectify this, the California Energy Commission contracted the authors to produce a scientifically based, geomorphic and ecological stream delineation method that project developers can use to inform the design and development of sustainable, low-impact projects in dryland environments. The *Mapping Episodic Stream Activity* (MESA) protocols described herein facilitate project permitting by providing a uniform delineation protocol; helps oversight agencies evaluate a project's potential impacts; and provides a formal method with broad application for developing land use and resource management plans, and evaluating land use and resource management practices.

Keywords: California Energy Commission, permitting application, fluvial processes, episodic streams, desert ecosystems, desert habitat, mapping protocols, jurisdictional watercourse

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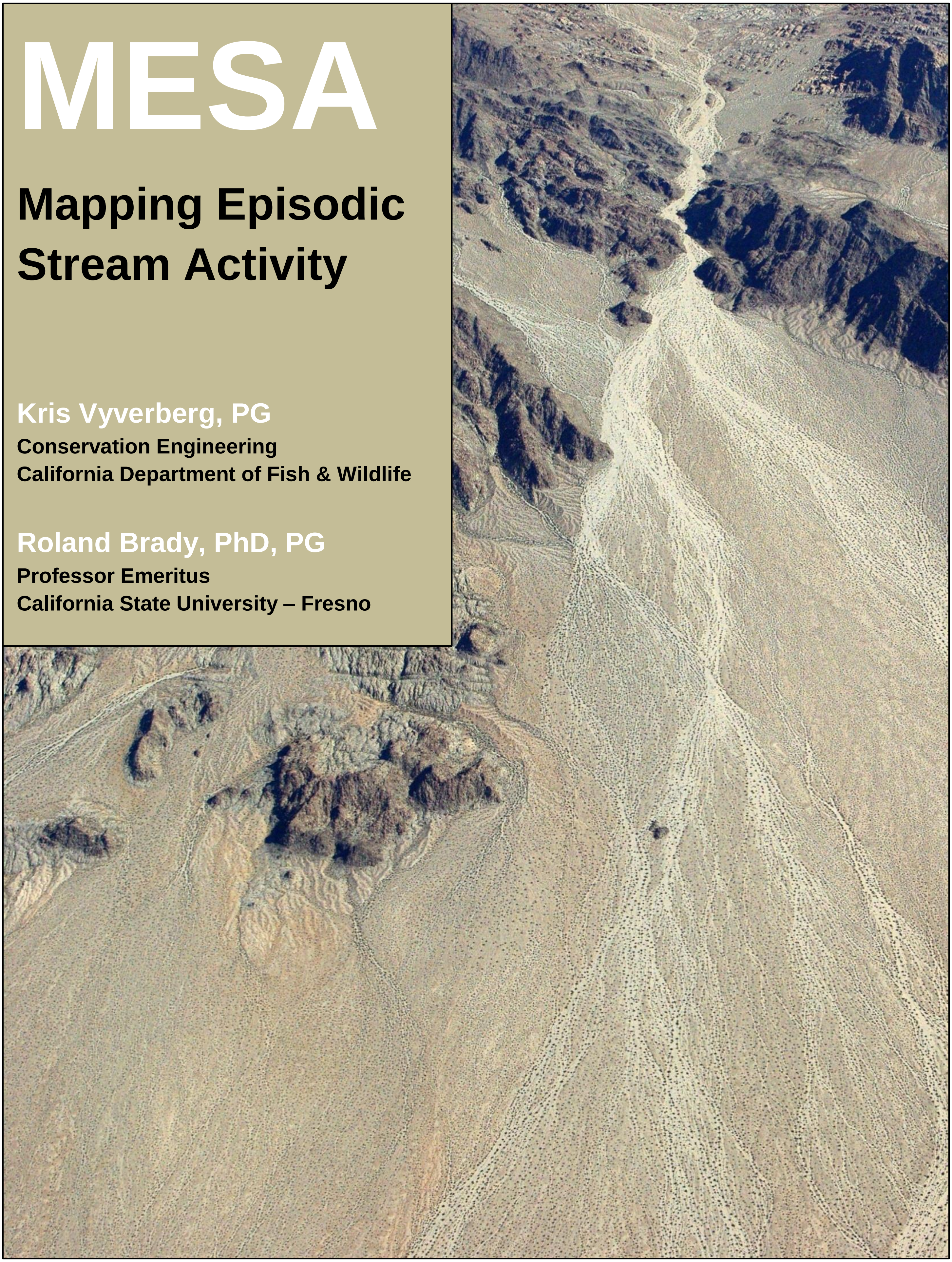

One of the most startling paradoxes of the world's drylands is that although they are lands of little rain, the details of their surfaces are mostly the products of the action of rivers. To understand the natural environments of drylands is to understand the process and forms of their rivers.
W.L. Graf (1988)

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Cover image: Aerial view of an unnamed episodic stream as it flows out of a boundary controlled reach, loses confinement and transitions to a distributary network of channels and alluvial fans, eastern Pinto Mountains, Joshua Tree National Park, Riverside County, CA. Photo taken April 2009, view to the north; Lat/Long: 34.0613, -115,4776. Photo courtesy of J. Lancaster, CA Geological Survey.

MESA ~ a Field Guide

Statement of Purpose

The authors Kris Vyverberg, Senior Engineering Geologist, Conservation Engineering, Department of Fish and Wildlife (CDFW) and Roland Brady, PhD, Consulting Professional Geologist prepared this document to provide the California Energy Commission (CEC) and energy project developers a science-based protocol for identifying and mapping dryland episodic streams.

MESA ~ A Field Guide to Mapping Episodic Stream Activity, the *Photographic Atlas of Indicators of Episodic Stream Activity* and the *MESA* mapping protocol are collectively intended to aid geologists, geomorphologists, and desert ecologists in the identification and mapping of episodic streams when water is absent, and has perhaps been so for several years. When combined with aerial photo interpretation of the landscape, correctly identifying and documenting surficial geologic indicators of fluvial activity and inactivity will allow determinations to be made regarding stream presence and the relative recency of fluvial activity. Landforms can then be linked with their processes, and the active watercourse differentiated from fluvially inactive uplands, terraces, and abandoned or relict channels. The results should better inform both desert ecosystem conservation plans and sustainable project development.

MESA is the product of a comprehensive field study and report prepared for the CEC in 2013. A summary of the study's scientific rationale, citations, and complete glossary have been incorporated in this *Field Guide*. The CEC study also included six stream mapping case studies including comparative evaluations of alternative methods that are available from K. Vyverberg at the address below.

We benefited from and appreciate the editorial and technical review provided by: Jeremy Lancaster, Engineering Geologist, California Geological Survey; Carolyn Chainey-Davis, Consulting Botanist; Todd Keeler-Wolf, Ecologist; Kit Custis, Engineering Geologist, Serge Glushkoff, Environmental Scientist, and Singleton Thibodeaux-Yost, Geologist, all at the CDFW.

Notes to the Reader

Terms in common use in the practice of stream ecology, geomorphology, and hydrology that are not defined in the narrative can be found in the *Glossary* at the end of this document. The first occurrence of such terms in the narrative is noted in **bold-faced** type.

Taking Criticism to Heart

The authors are hopeful that this field guide will improve and facilitate the mapping of dryland episodic streams. Readers and practitioners with comments or recommendations to improve this field guide and the mapping and conservation of these stream ecosystems are encouraged to contact:

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Episodic Streams of California's Deserts

This *Field Guide* focuses on streams of the arid and semi-arid Mojave, Sonoran, Great Basin, and eastern Sierra desert regions of California – regions characterized by low and highly variable precipitation, and evapotranspiration that exceeds the mean annual precipitation by 10 inches or more. Lands receiving less than 8 inches of precipitation are considered "arid", those receiving between 8 and 20 inches are considered "semi-arid"; collectively these areas are referred to herein as drylands (USFS 2009).

Infrequent but generally intense precipitation combined with the cumulative effects of highly variable topography, low vegetation cover, and high evaporation and **transmission losses** create stream systems that respond more rapidly to rainfall, have greater variations in flow between **runoff** events, and shorter duration flows than their temperate-region counterparts. Although streams of all types occur in the drylands of California, ephemeral streams – those that flow only during and shortly after precipitation are most common. The United States (US) Environmental Protection Agency estimates that ephemeral and **intermittent streams** (also referred to as episodic streams) comprise 66 percent of all streams in California – an estimate that is likely low given that it was derived from a topographic map scale (1:100,000) too small to show stream channel lengths less than 1 mile (Levick *et al.* 2008).

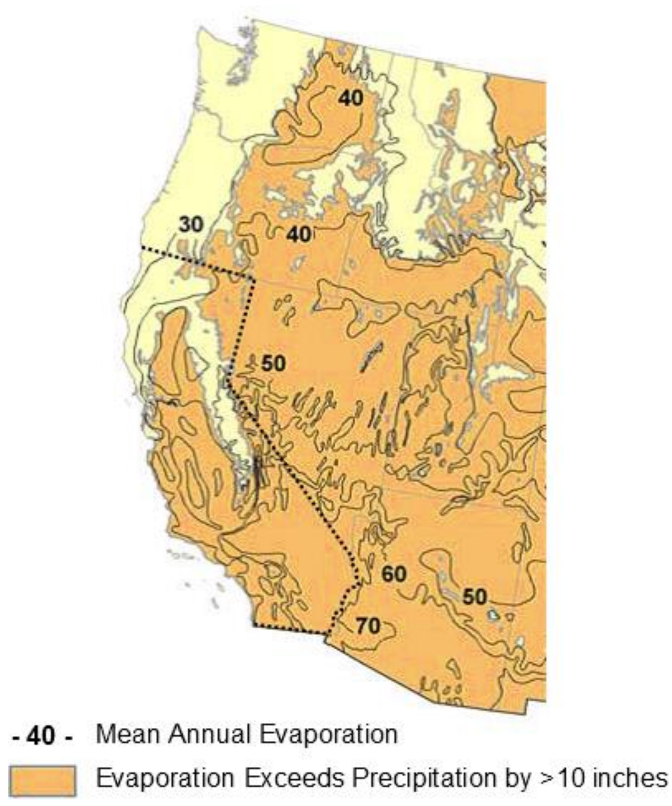


Figure 1. Geographic extent of dryland regions (in orange). The mean annual evaporation in these regions exceeds annual precipitation by 10 inches or more. *Graphic adapted from USFS 2009.*

Physical Characteristics of Dryland Episodic Streams

While the hydrologic controls are fundamentally the same for streams everywhere, the great variability in rainfall intensity and runoff volumes, and low durations of flow for dryland streams produce a much less ordered pattern of processes and stream forms than for perennial systems (Thornes 2009). Because the hydrologic and morphologic characteristics of dryland streams are often outside of the “normal” range of their temperate and humid region counterparts, models describing the hydrology, sediment transport characteristics, and resultant channel forms of temperate and humid region **fluvial** systems cannot be reliably applied to dryland streams. Characteristics that distinguish dryland streams from those in temperate-regions include:

- Shorter-lived, more localized, and more highly variable flow in response to precipitation patterns that vary greatly on an annual and interannual basis, and that combined with the cumulative effects of highly variable topography, evaporation and transpiration, and seepage losses through the stream bed results in dryland stream systems with more rapid responses to rainfall, greater variations in flow between runoff events, and shorter duration flows than their temperate-region counterparts
- Higher peak discharge magnitudes (relative of average flow).
- Higher runoff per unit area. Rainfall in dryland environments tends to be more intense, and runoff is enhanced by sparse plant cover and surface organic matter, **soil crusts**, and the presence of gravel-covered surfaces underlain by stone-free **soil** horizons of **eolian**-derived fine sediment that inhibit the infiltration of water.
- Runoff contributions to stream flow can be two or three times that received from precipitation alone making dryland stream ecosystems more susceptible to changes in runoff-supplied water (McDonald et al. 2004; Schwinning et al. 2010).
- Flows decrease rapidly downstream due to evaporation and seepage of surface flow into the unconsolidated sediment of the channel bed and banks. These transmission losses reduce overall stream discharge whether or not there is input from tributaries downstream. These losses also reduce the downstream flood peaks and total runoff volumes that transport sediment and form channels.
- Often all but the largest runoff tends to coalesce in small, low-order tributaries where it infiltrates, rarely flowing to the larger streams. These small, frequent and highly local flow events and the moisture retained and available to the biological community from these low-order channels indicate **ecohydrologic** significance to the landscape that exceeds their modest size.
- More intense rainfall and less vegetation protecting the soil lead to higher concentrations of **suspended** sediment and greater transport rates of **bedload** sediment. However, due to enhanced infiltration into the unconsolidated sediment of the channel bed and banks, only in the larger flows associated with higher intensity, and longer duration runoff is sediment transported the entire length of the channel.
- High-magnitude, low-frequency flows combined with high sediment load, downstream flow losses, and declining sediment transport capabilities create highly varied, transient channel morphologies that challenge conventional notions of channel form and channel stability, and confound determinations of active versus inactive stream processes (Figure 2).

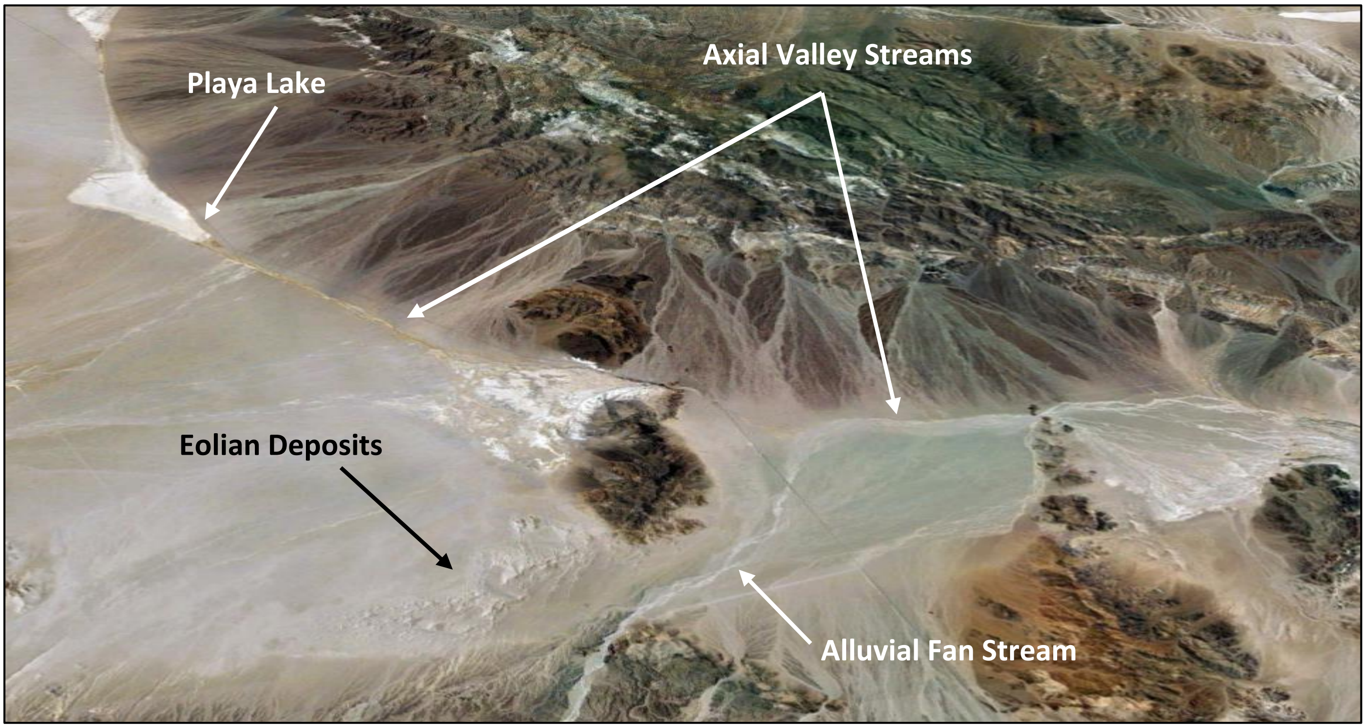


Figure 2. Geomorphic context of typical episodic streams in the drylands of California. The fluvial activity of these streams distribute water and nutrients over vast areas, and supply sand from upland sources to eolian deposits and desert dune environments. *Photo Google Earth, 2013*.

Ecological Attributes of Dryland Episodic Streams

Although this *Field Guide* focuses on the physical and hydrological considerations for recognizing, defining, and mapping dryland episodic streams, the impetus for this work is the conservation of desert stream **ecosystems** through development of environmentally sensitive and sustainable projects. Recognizing the following relationships that form the bases of **ecohydrologic integrity** and **resiliency** is the starting point:

- The biological communities of dryland streams and **washes** often provide habitat values distinct from the adjacent **uplands**. Although the dominant species may be the same (for example, creosote bush and white bursage), vegetation on fluvially active surfaces may have greater species diversity, or exhibit greater shrub density, greater vegetative cover, and more robust vegetation than the adjacent uplands.
- However modest the flow of episodic steams, they are no less essential to the ecosystem than are perennial streams in that they move water, sediment, organic debris, and nutrients; recharge groundwater; and provide physical and biological connectivity and habitat for many local species (Gomi *et al.* 2002; Levick *et al.* 2008; Shaw and Cooper 2008).
- Conserving a stream ecosystem ultimately depends on protecting the surficial geologic, fluvial, and biological processes that operate on decadal and longer time scales, and that collectively create and maintain the integrity of the habitat upon which the associated flora and fauna depend (Fish and Game Code (FGC), Division 5, Chapter 1, Section 45; CDFW 2013).
- The variability in water depths and velocities across a stream channel result in physical complexity that supports **geomorphic** integrity and ecosystem diversity (Thoms 2006).

- Because stream channels move sediment, seeds, and organic material, as well as water, they support habitats and biological populations beyond the watercourse itself – for example, by moving sand between **headwater** sources down the channel to wind corridors that carry it to augment or create offsite dune habitats of species such as fringe-toed lizards and other dune-dependent species like Eureka Dunes evening primrose, or by concentrating and germinating seeds of rattlesnake weed and other late season annual plants in the saturated sediment at a stream terminus to provide summer food for the desert tortoise and other animals.
- Because low-order, ephemeral streams are susceptible to changes in runoff-supplied water, conserving and maintaining the connection with the surfaces that deliver this water is critical to maintaining the functional integrity of the stream and associated ecosystem (McDonald et al. 2004; Schwinning et al. 2010). Project designs that maintain the natural form of streams but isolate them from their surface water runoff areas make them wholly dependent on local precipitation that climate change models suggest is already in decline (Miller et al. 2009).

Notes on Terminology

The practice of stream mapping for natural resource assessment is troubled by the use of colloquial terminology that has often lost its geomorphic and hydrologic context. This problematic terminology exists because: 1) many practitioners delineating streams are from disciplines other than the physical sciences of geology, fluvial geomorphology and hydrology; 2) terms in common use have not been as rigorously defined in the scientific literature as practitioners from these other disciplines might expect; and 3) little guidance has been provided on more appropriate nomenclature.

An example of this is the common use in stream delineation reports of the term *"sheetflood"* to signify a shallow flood condition that occurs where the channel loses its form, and thus interpreted to represent the end of an identifiable stream. However, the term is rarely defined in these reports or its usage accompanied by supporting citations. Since there are at least seven rather contradictory definitions of **sheetflood** in the literature, it should be no surprise that the use of this term tends to confound rather than illuminate one's position on the fluvial landscape (North and Davidson 2012).

Perhaps the best example of the need for clearer and more rigorous nomenclature is the inconsistent terminology used to define a stream. The definition and supporting terminology used herein, and of this writing used in practice by the natural resource management agencies having principle responsibility for conserving the waters of the State, is outlined in the section below.

The recommended usage and geomorphic context for other commonly used terms are provided in the accompanying *Glossary*.

Stream and Watercourse

A stream is defined as *"a body of water that flows perennially or episodically and that is defined by the area in which water currently flows, or has flowed, over a given course during the historic hydrologic regime, and where the width of its course can reasonably be identified by physical or biological indicators."* The historic hydrologic regime is defined as circa 1800 to the present (CDFW 2010).

A stream begins at the location where water flows away from its source in or along a defined course. Its source may be a spring, a wetland, a pond or lake, but most often ephemeral streams in California begin where runoff from the surrounding, less permeable, upland surfaces coalesces in **swales** to initiate stream flow. Where such a swale is the head or source area of a stream, it is considered an integral part of the stream system (CDFW 2010).

Diffused surface runoff like **overland flow** or **sheet flow** occur on the land without having been part of a watercourse and neither the flow nor the landscape over which it occurs is part of a watercourse until runoff begins to coalesce and to modify the landscape to form swales that in turn yield stream flow. Here the identity of water as a form of diffused surface runoff is lost and it becomes a stream.

A stream's form may vary along its length and cross section. It can have one or more channels that may be active or that receive water only during high flow. Associated features such as **braided channels**, **low-flow channels**, **active channels**, banks associated with **secondary channels**, **floodplains, islands**, and stream-associated vegetation, may occur within the larger channel complex defined as the **watercourse** and are indivisible from it by virtue of their structural and fluvial connectivity (CDFW 2010).

The typical stream has a defined bed and banks that rise vertically above and horizontally away from it. However, in episodic streams, the banks can be slight or nearly imperceptible, and hence, the extent of channel confinement can vary along the line of flow. Regardless of how subtle a channel's topography, whether a **single-thread** or **compound** form, or its flow intermittent or ephemeral, if the physical and biological evidence for the location of its waters at their highest level of confinement can reasonably be identified, then this line of flow defines the watercourse.

A stream or watercourse is not defined by particular flow events, such as **bankfull flow** or **ordinary high water**, but rather by the local topography or elevations of land that confine a stream to a definite course when its waters rise to their highest level. Thus, the watercourse is a stream, and its boundaries define the maximal extent or expression of a stream on the landscape.

A floodplain is a relatively flat area of land associated with a stream, and over which water and sediment from a parent stream flows when the capacity of the channel is exceeded. Floodplains parallel stream channels but may also occur at the terminal end of a stream where the channel joins an **axial valley stream**, transitions into a **playa**, or the channel ends and its flow subsides into the ground to join the groundwater. Not every stream has floodplains, but where floodplains occur they are considered integral to stream function and to define the outermost bounds of a watercourse in cross section and length.

Floodplains and their surfaces are defined by the lateral extent of water that overflows subordinate channels but that has not escaped the main watercourse. Floodplain overflows and the floodplain areas they inundate are associated with typical or ordinary flow occurrences; they are not extraordinary event **flood waters** that leave and do not return to their usual channels, or that overflow areas not ordinarily inundated. Even though these overflows may consist of a large expanse of water on either side or at the terminal end of the main channel, these waters and the floodplain surfaces they occupy are not separated from the watercourse and remain a part of it (Hutchins 1971). This connectivity between floodplain, channel and watercourse is most readily demonstrated by the return of stream flow to subordinate channels when high water recedes. However, when runoff is low or of short duration, overflow onto a floodplain will often seep into the ground before it can return to the channel. Connectivity between these waters, their floodplain, and the larger watercourse will be demonstrated by the presence of fluvial deposits and the absence of topographic barriers between the floodplain and watercourse. Surface flows lost by infiltration alone do not define the bounds of a watercourse.

Floodplains associated with single-thread and compound streams tend to be more readily identified than those associated with the **distributary streams** that can dominate low gradient **alluvial fan aprons, alluvial plains**, or where a stream reaches the edge of an ephemeral lake (i.e., playa). In these areas, downstream decreases in surface flow and in-channel sedimentation result in channels that lose definition with decreasing width and depth so that when runoff occurs it tends to coalesce and to follow broad flow zones rather than easily defined channels (Graf 1988). The shallow, relatively uniform expanse of water that occurs in these areas is often used as an indicator of the release of water from confinement because a stream has ceased to exist. However this conclusion would not be correct if the water has merely coalesced from overflow onto parallel or terminal floodplains but has not escaped the bounds of its broader watercourse as described above.

Mapping Streams

The people of California place great value on streams and the fish, wildlife, and habitats associated with them, and have put various measures in place to protect and conserve these natural resources. One measure, embodied in the form of the Fish and Game Code, requires that the Department of Fish and Wildlife be consulted if a proposed development project has the potential to detrimentally effect a stream and thereby the fish and wildlife resources that depend on a stream for its continued viability (FGC Division 2, Chapter 5, section 1600-1616). The purpose of the consultation is to characterize the extent and nature of all stream resources on landscapes being considered for modification. A map of these resources is made and used to inform development project design so that the affected streams can preferably be avoided and conserved, or where this is not reasonably possible, to identify the extent of the stream resources that may have to be compensated for by conserving similar resources in some manner.

Many different tools are available to physically characterize streams, such as hydraulic models used to evaluate threats of flooding to manmade environments, or remote sensing tools used to interpret landform relationships. Depending on the needs driving the mapping effort, the tools used and the level of detail required to answer the questions posed will vary. A higher level and different type of detail may be needed for computer-generated flood analyses that must consider a stream's sediment transport characteristics and **watershed** contributions well beyond a project's physical boundary. In contrast, locally focused questions of stream presence and processes wholly within proposed project boundaries might be resolved at a lower level of detail through interpretation of aerial photograph signatures combined with the collection of site-specific geologic evidence.

It is the latter that is the starting point for the mapping described here, although obtaining the requisite evidence to answer questions pertinent to the conservation of streams within a project boundary may require going further afield and drawing upon more sophisticated analyses. This mapping is not blind to flood management considerations, nor to the ecological relationships between a stream and its surrounding landscape – all of which can uniquely inform the type of mapping and level of detail called for. It is assumed that where there is water there will be life and the habitat used to sustain this life, but as we largely leave the hydraulic analyses to the engineers, so we leave characterizing the details of the ecosystem relations to the biologists.

Current Stream Delineation Practices

Given the temporal, spatial and subtle variation of the episodic streams' channel form; the long **recurrence intervals** between their highly localized and difficult-to-predict surface-flow events, and the brief assessment periods when flow does occur, most stream ecologists and hydrologists and their funding entities have focused their studies on streams defined by the relatively regular and predictable presence of water, and with forms and processes more easily defined. There is currently no single or consistent science-based method for mapping episodic streams. In the absence of such a tool, episodic stream presence and extent is most often determined by the use of coarse-scale **plant community** classifications combined with various stream typing classification systems, both of which were developed for other purposes.

Vegetation mapping and surveys have greatly enhanced our understanding of landform-habitat relations. Done well, vegetation maps indicate the local ecohydrological relations relative to the underlying deposits, and so are important to interpreting landforms. For example, recent work in the Mojave Desert demonstrated that, with the exception of the youngest and oldest surficial geologic deposits, plant cover density and species composition vary consistently with the age of the land surface (McAuliffe and McDonald 1995; Bedford et al. 2009; Miller et al. 2009). The investigators found that soils lacking strong horizons, and those with high gravel content, like the well-drained gravelly soils typical of recent stream deposits, have high water infiltration rates, allowing water to infiltrate to deep moisture zones protected from evaporation and where it is available to deep-rooted vegetation such as *Larrea tridentata* (creosote bush). These results provide first-order confirmation of soil moisture characteristics and the responses of creosote bush to soil moisture; they do not necessarily indicate the presence of stream deposits. Similarly, the absence of large, verdant stands of creosote do not prove that the associated landscape form is now fluvially inactive, or never was a stream. While this work has ascertained the importance of the soil-water retention and availability properties of surficial deposits relative to the pattern and density of creosote, it may not apply to other dryland environs where creosote bush is less pervasive or is absent altogether. Many similar ecohydrological variables with the potential to affect stream-plant relations remain in question. Until the relationships between desert vegetation species composition and streams are better documented and understood, the use of vegetation as a proxy of soil texture can be used to inform landscape interpretation, but not used as a proxy for determining watercourse presence and extent.

Stream condition assessment **protocols** such as the California Rapid Assessment Method (Collins *et al.* 2008), or stream classification tools like Applied River Morphology (Rosgen 1996) were not developed for use as stream delineation tools in the desert landscape or anywhere else, and they should not be used as such. Similarly, methods to determine ordinary high water (OHW) levels are appropriate for defining the existence or extent of streams subject to Federal jurisdiction, but OHW protocols should not be used to define which streams are subject to State jurisdiction (Lichvar et al. 2004, 2008; CDFW 2010).

Considering the lack of guidance and protocols to map desert streams, their episodic flows, often complete absence of iconic riparian vegetation, and channel forms that challenge conventional notions of what a “real” stream should look like, it is perhaps understandable why many episodic streams are inappropriately excluded or never identified in stream delineation reports.

This *Field Guide* illustrates and describes fundamental stream forms, processes, and functions that must be recognized and identified in order to correctly delineate or map episodic streams. It provides examples of common surficial geologic indicators of fluvial activity and inactivity that are <u>a starting point for interpretation</u> of landform relations and stream activity – not the interpretation itself. This should be done in collaboration with a geologist (or geomorphologist) with expertise in episodic streams and their processes because it relies on methods that require special training, extensive field experience, and understanding of natural surficial processes outside the practice of many non-geologists.

Use of Surficial Geology to Map Dryland Episodic Streams

Considering the infrequent occurrences of surface flows – oftentimes years – questions regarding the presence, form, and extent of activity of episodic streams are best answered by examining the evidence left on the landscape by the processes that created them, particularly: 1) the geology of fluvial deposits,

2) the landforms modified by stream activity, and 3) the features formed from **terrestrial processes** that operate on fluvially inactive landscapes. This evidence is collectively defined as the surficial geology of an area, and its study and documentation allows the most subtle features of the physical landscape to be understood.

Surficial geology describes the geologic characteristics of the landscape and surface materials in terms of the fundamental processes that form these characteristics. Arid land geomorphic processes that form sedimentary deposits can be broadly grouped as: (1) terrestrial (mass-wasting or gravity-transported); (2) fluvial (water-transported); and (3) eolian (wind-transported). Each has unique characteristics that are reflected in the physical properties of their deposits, and in the morphology of the deposit surface (Miller et al. 2009).

If a portion of a landform becomes isolated from its original watershed and watercourse, it ceases to receive new deposits and its surfaces will begin to develop specific physical characteristics of its age. These deposits and their morphologies are then acted on and further modified by erosion and weathering that reduce the topographic relief; round surface margins; change the landscape color, and produce **desert pavement**, **rock varnish**, and distinctive soil horizons.

These characteristics, products of a landform's depositional history, and level of stability, can be used to interpret the relative order of age by comparing a particular surface's degree of development or modifications to those observed on other surfaces nearby.

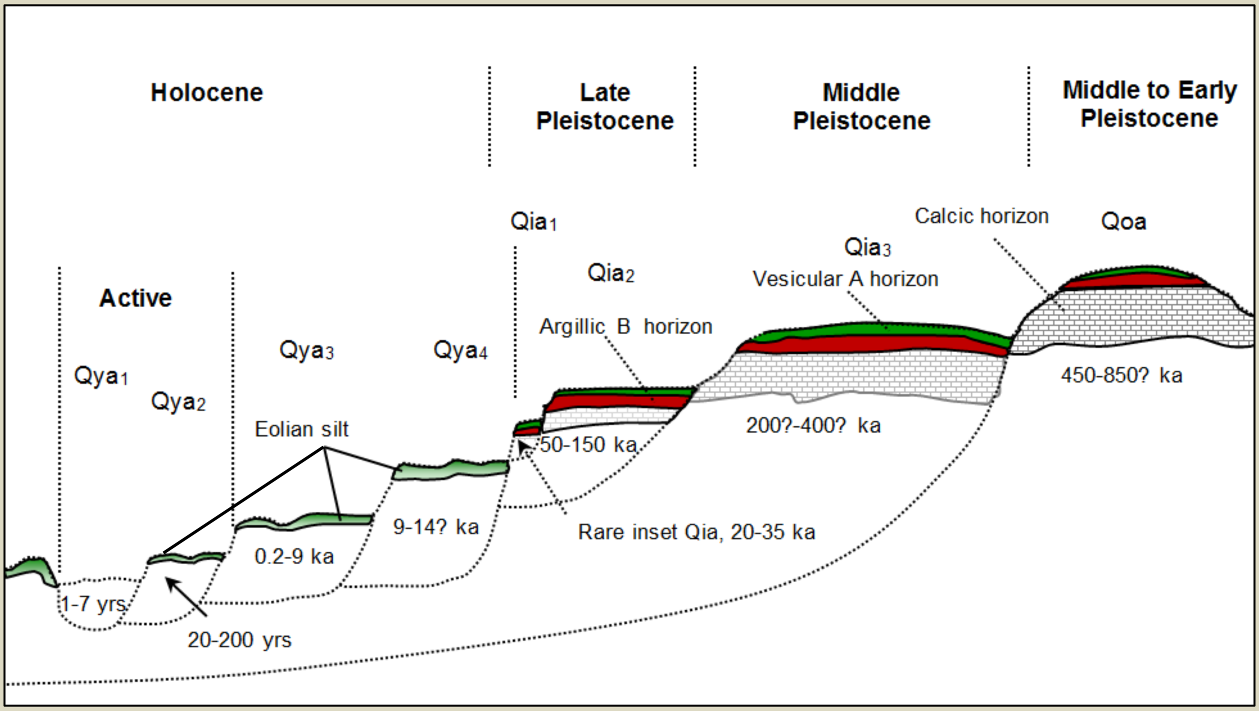
Although absolute (or numerical) dating techniques such as **radiocarbon** or **optically stimulated luminescence** might be more appropriate for defining flood hazard zones, the use of the relative age dating techniques described here, are in common use in the deserts of the southwest and provide a cost-effective and appropriate way to estimate the age range of alluvial landforms and the recency of fluvial deposition, and thus stream presence.

The characteristics of these surficial deposits and the evidence of the processes acting on them are herein collectively referred to as "indicators" of either fluvial activity or inactivity. For the purpose of mapping episodic streams, the surficial materials of principal interest are those with ages between less than one year to up to ~200 years old, although knowledge about the characteristics and role in stream function of older landforms and surfaces is needed to inform interpretations of stream presence (CDFW 2010).

The following inset diagram illustrates an idealized cross section of alluvial surfaces where progressive stream down cutting and infilling has formed a series of channels and terraces (incised and abandoned floodplains). From left to right it depicts changes in surface morphology from youngest to oldest surfaces during the past million years for the Mojave region. The model, based on numerous field observations, links alluvial landforms with their processes, and differentiates among the active watercourse, **abandoned** or **relict channels**, **terraces**, and fluvially inactive uplands (Miller et al 2009).

The surficial geologic mapping method prescribed in this guide is conducted by first interpreting images of remotely sensed landforms and surfaces, and then undertaking a field examination of landforms; surface indicators of fluvial activity and inactivity; and sometimes soil profiles in shallow, hand-dug pits. Undertaking surficial geologic mapping of this type requires skill and experience with aerial photo interpretation, geology, fluvial geomorphology, soil development, and the basic ecology of dryland environments.

Alluvial Surface Development in the Mojave



Although no actual vertical elevation is implied, the greatest elevation differences between active channels and older terrace deposits usually occurs high on the fan and may be tens of meters. Low on the fan, the differences between these units may be less than a meter.

Qya1: Quaternary young alluvium (Qya). Qya1 represents active stream channels and their deposits; channels tend to lack vegetation and show evidence of recent stream flow activity.

Qya2: Older floodplain surfaces with established vegetation. Qya2 surfaces typically have the greatest biomass of all surfaces, probably because roots can take advantage of the loosely consolidated deposits and access to moisture at depth. As roots stabilize, the Qya2 overbank fines increase the moisture retention.

Qya3 & Qya4: Mid- to older-**Holocene**, alluvial fan surficial deposits elevated and isolated from active channel erosion. These surfaces have a thin, intermittent soil, often with overlying deposits of floodplain overbank sediment and wind-blown silt that are generally un-eroded and sparsely vegetated relative to Qya2 surfaces.

Qia1, Qai2, & Qia3: Progressively-older, late **Pleistocene**-age deposits and surfaces from about 20,000 to 400,000 years old. These deposits and surfaces possibly correspond to cycles of aggradation and erosion corresponding to alternating wet and dry climatic cycles. Older Qia surfaces tend to have less vegetation than the younger Qya surfaces, and may have well-developed desert pavement that caps a thin silty, loam soil (**vesicular A horizon**) that overlies a more weathered, dense clay-rich subsoil (Argillic B horizon). Qai1 to Qai3 surfaces are best preserved in the middle part of "stable or well-developed" alluvial fans, or occur as elevated, bench-like terraces along stream channels with broad valleys.

Qoa – Middle Pleistocene channel deposits and terraces older than 400,000 years. These deposits are typically highly eroded, and are locally represented as rounded hills consisting of tightly cemented alluvial gravels or ancient soils horizons, typically along the range front of mountains. Qoa deposits are usually cemented by calcium carbonate “caliche” (calcic horizon) in the lower subsoil. Older Pleistocene and later **Tertiary** deposits and surfaces have long since been eroded away in the Mojave region, or are locally incorporated in older basin-fill deposits, so generally no surface expression remains

Illustration and text adapted from David M. Miller (2009) and used by permission.

The Tool Box

This *Field Guide* is intended to help geologists and desert ecologists identify and map episodic streams where water is absent and has been absent perhaps several years or more. To accomplish this, the *Field Guide* includes a variety of essential and complementary tools that – when combined with aerial photo interpretation of the landscape, and recognition of surficial geologic indicators of fluvial activity and inactivity – will allow determinations to be made regarding stream presence and the relative recency of fluvial activity. Landforms can then be linked with their processes, differentiating the active watercourse from fluvially inactive uplands, terraces, and abandoned or relict channels. The results should better inform both desert ecosystem conservation plans and sustainable project development.

The primary tool is the *Photographic Atlas of Indicators of Episodic Stream Activity* which is a visual reference for documenting fluvial activity or inactivity over time. The indicators of fluvial activity and inactivity are organized in a matrix of fluvial and terrestrial features in the watercourse or upland, and are listed alphabetically within their organizational categories. Explanatory text accompanies each indicator:

- **Name**: Descriptive (formal, common, and alternative variations may be noted).
- **Description**: Material (soil, sand, gravel, mud, rock, salt), Forms (cuts, benches, depressions, sheets, ramps, wracks, swales, ripples, ridges, channels, dunes), and Surfaces (etching, rounding, staining, **rubification**, varnish, lineations, crusts)
- **Process**: Terrestrial (weathering, deflation, soil formation), Fluvial (erosion, transportation, deposition), or Ponding, Evaporation, and Eolian (sand transport & deposition)
- **Occurrence**: Upland and Watercourse (surface, substrate, channel bottom, bank, bar, bench).
- **Location**: Geographic location of the photo.

The *Mapping Tools* that accompany the *Atlas* include a *Representative Watercourse Cross Section with Associated Geomorphic Units, Guidance on Defining Watercourse Boundaries, Annotated Definitions of Stream and Upland Terminology*, an *Episodic Stream Indicator Data Sheet,* and several diagrams for making field estimates of particle size and percent cover.

The *Data Sheet* is integrated with the *Atlas* to provide one approach to identifying landscape forms, their surficial geology, and organizing and documenting the observations made to determine the boundaries between active streams and fluvially inactive uplands. Transitional areas such as terraces can also be accounted for, and indicators of **out-of-channel flow** can be used to identify and locate lateral and terminal floodplain areas that lie within the bounds of the broader watercourse.

Because the characteristics of the vegetation on fluvially dominated surfaces, as compared to inactive or upland surfaces, is an important, (but secondary), indicator of stream presence, the *Data Sheet* asks for estimates of percent vegetative cover or plant density, and the size or vigor of the vegetation in fluvial versus upland environs. The species composition of the dominant and characteristic **shrubs** and perennials can be noted if the stream delineator has the expertise. This basic ecological information, combined with identifying and documenting the dominant physical processes active on the landscape is a starting point for considering the operative relationships between these processes and the surrounding natural and biological resources.

Despite the growing capabilities of remote mapping technologies, on-the-ground reconnaissance is critical to accurate stream identification and, ultimately, to developing an environmentally compatible project design. When combined with guidance on landform and watercourse recognition, high-resolution aerial imagery and GIS technology provides preliminary information that is the foundation of any watercourse delineation map but that also must be confirmed and augmented with field observation and measurement: boots on the ground are still required.

The protocol for *Mapping Episodic Stream Activity [MESA]* consists of three steps:

1. Recognizing the stream forms and processes – gathering information on a site's physical characteristics in collaboration with an appropriately experienced geomorphologist or licensed **Professional Geologist** (PG) – is an essential first step in delineating episodic streams,
2. Documenting the extent of on-the-ground indicators of fluvial activity and inactivity, and
3. Mapping the watercourse including any subordinate features such as low-flow and secondary channels, or floodplains.

This approach answers two key questions when mapping dryland streams: 1) Where are the streams on the landscape and 2) How might a streams' location change with variations in flow and over time?

With temperate-region streams, we need only to look for water seasonally at flood stage to answer both questions, but in the dryland environment, this strategy would require decades. However, using the *MESA* protocol, an episodic watercourse can still be mapped to show the total area over which it has been active during the historic period. For the natural resource manager, this provides an accurate characterization of stream contributions to an ecosystem that is adapted to the episodic delivery of water, nutrients, and sediment. For the project developer, the map accurately characterizes the location and extent of active stream processes – essential information when considering implications to infrastructure investment, and sustainable project design.

Step 1: Recognizing Dryland Episodic Stream Forms and Processes

- Review and select current aerial imagery of the project area, and others that show stream activity across water years. Select high-resolution base map imagery that clearly shows landscape signatures and that can be mapped at a minimum scale of 1:6000 (1 inch = 500 feet) (Figure 3).
- Review the sections on *Channel Forms* and *Geomorphic Units* in this *Field Guide* before undertaking the aerial photo interpretation or the ground-based mapping.
- In consultation with a geologist and geomorphologist identify the basic geological and geomorphic units apparent in the aerial imagery. Pertinent background information is generally available from the US and California Geological Surveys (CGS 2012).
- Select and outline the watercourses and related geomorphic forms or units (e.g., floodplain, terrace, **interfluves**, islands) based on their aerial signatures, such as changes in landscape color, vegetation density, and **drainage** pattern (Figure 4). Identify any **anthropogenic disturbances** in the project area.
- Finally, select areas for locating the transects that will be used to determine the boundaries of the geomorphic units in step #2 and locate them to encompass a full watercourse cross-section, or a longitudinal survey for smaller first- or second-order streams (Figure 5).

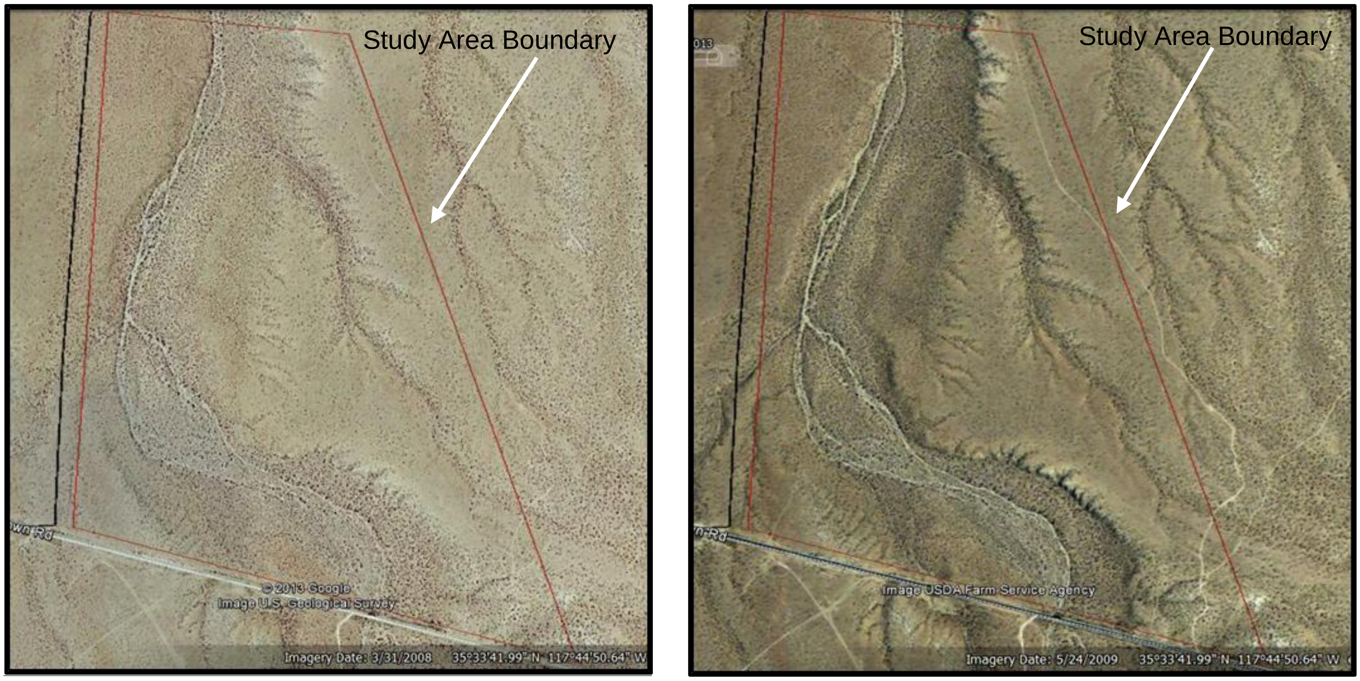


Figure 3. Watercourse base map imagery. Many sources of aerial photography are available to facilitate watercourse identification and to produce an informative watercourse map. The high-resolution imagery available from Google Earth is an inexpensive and ready source. It allows one to quickly search a database for historical imagery archived from a variety of sources over the last several decades, and then select images that best show watercourse signatures, allow comparison of watercourse behavior or appearance between water years, or show pre- and post-anthropogenic influences on the landscape.

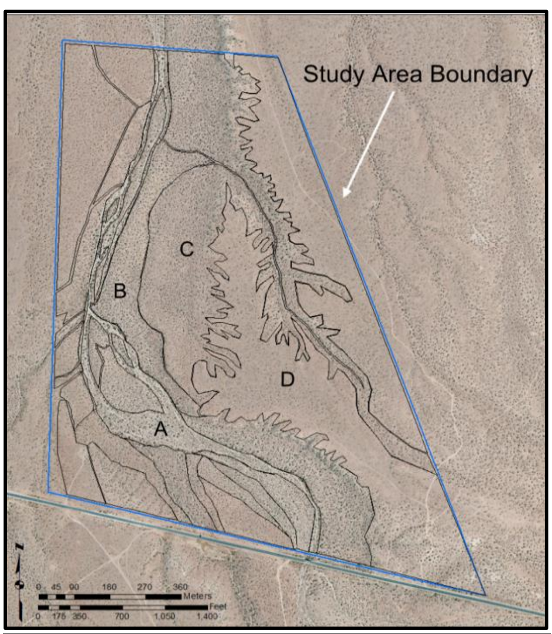


Figure 4. Select and outline watercourse and related landform boundaries based on aerial photo signatures such as changes in landscape color, vegetation density, and drainage pattern. **A** = Light color, sparse vegetation; **B** = Dark even color, vegetated; **C** = Distinct pale color, smoother surface, less vegetation; **D** = Pale color, smooth surface, sparse vegetation.

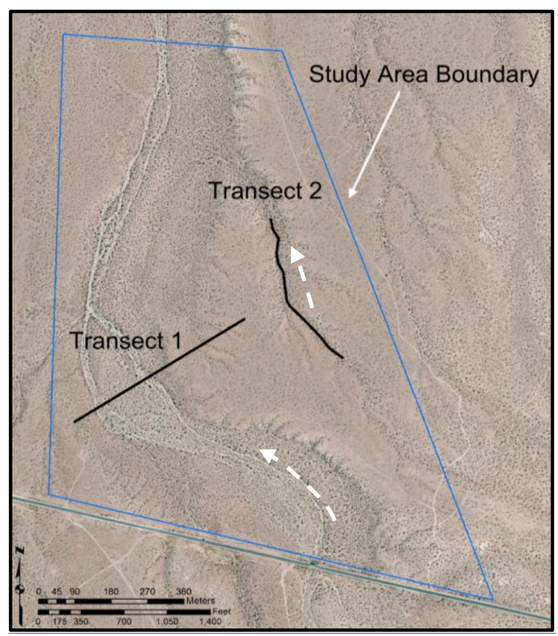


Figure 5. To refine the remotely determined landform boundaries, select transects for field verification of the surficial geologic and biologic evidence for stream presence. Note Transect 2, a longitudinal survey as suggested for first order streams. Direction of stream flow is indicated by the dashed white arrows.

Step 2: Documenting Indicators of Fluvial Activity and Inactivity

- In the office, complete the prefatory section of an *Episodic Stream Indicator Data Sheet* (included herein).
- Review the *Photographic Atlas of Indicators of Episodic Stream Activity* during the pre-field review and have a copy available during the ground-based mapping to ensure accurate identification of the indicators in the field.
- Once in the field, walk the selected reconnaissance transects to identify the boundaries of the geomorphic units, and document the presence and absence of all indicators of fluvial activity and inactivity on each unit.
- Use the sample *Percent Landscape Cover Diagrams* to make the estimates of percent substrate particle size and **percent total** vegetative cover (all shrubs and perennials combined).
- Walk a minimum distance of 100 feet upstream and downstream of the transect and note changes in the plant species composition between different geomorphic units. For example, there may be species present along the banks of the channel that are not present in the adjacent floodplain, or species present in the floodplain that are not found in the adjacent upland. Samples of the dominant or characteristic species unfamiliar to the surveyor can be collected for later identification by a qualified botanist or ecologist. Also note changes in shrub density between the different geomorphic units (the quantity of shrubs and perennials in a given area), as well as changes in the size or vigor of the dominant shrubs (e.g., in height and width). Note also any changes in the abundance (quantity) of certain species between units (Figure 6).
- After walking the full length of each transect with the preliminary map of the watercourse boundary and geomorphic units, and documenting the fluvial (or upland) indicators in each unit, adjust the mapped unit boundaries as necessary.
- Photograph the points of transition between geomorphic units, and between the outer watercourse boundary and the adjacent upland. Note and photograph any additional indicators or characteristics not in the checklists that were used to identify the units or to justify the mapped boundaries of the units.
- Using the information above, draw a watercourse cross-section that identifies the fluvially active and inactive geomorphic units (Figure 7).

Step 3: Mapping the Active Watercourse

- Use the *Annotated Definitions of Stream and Upland Landforms* to guide mapping of **dormant**, abandoned, or relict channels or terraces that are no longer functionally part of the watercourse.
- Use the *Guidance for Determining the Watercourse Boundaries* to determine areas of fluvial activity and inactivity and map the watercourse boundaries (Figures 8 and 9).
- Draw upon other resources such as FEMA flood maps (Federal Emergency Management Agency), State and local highway department stormwater management plans, and project-related hydraulic analyses and stormwater management plans to help refine the watercourse boundaries. See *Notes to the Stream Delineator and Project Reviewer,* (1) Related Stream Delineation Resources for a discussion of the limitations in the use of maps and tools developed for different purposes.

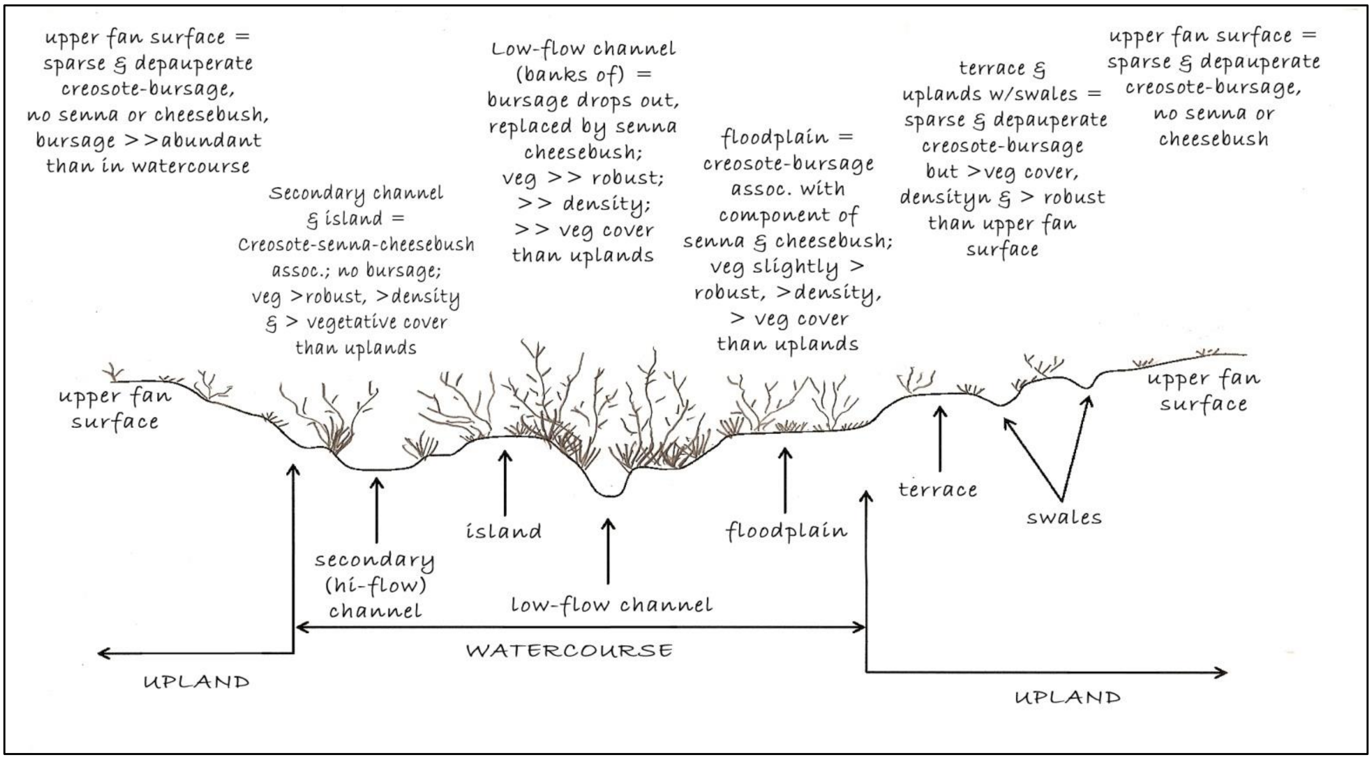


Figure 6. Representative watercourse cross-section of vegetation from data sheet that identifies points along the transect where the vegetation changes along a gradient from low-flow channel to the upper fan (upland). Characteristics of interest are the changes in the species composition, overall vigor or size of the vegetation, percent total (**absolute**) vegetative cover, density (i.e. number of shrubs/perennials, and changes in the **abundance** of the dominant species

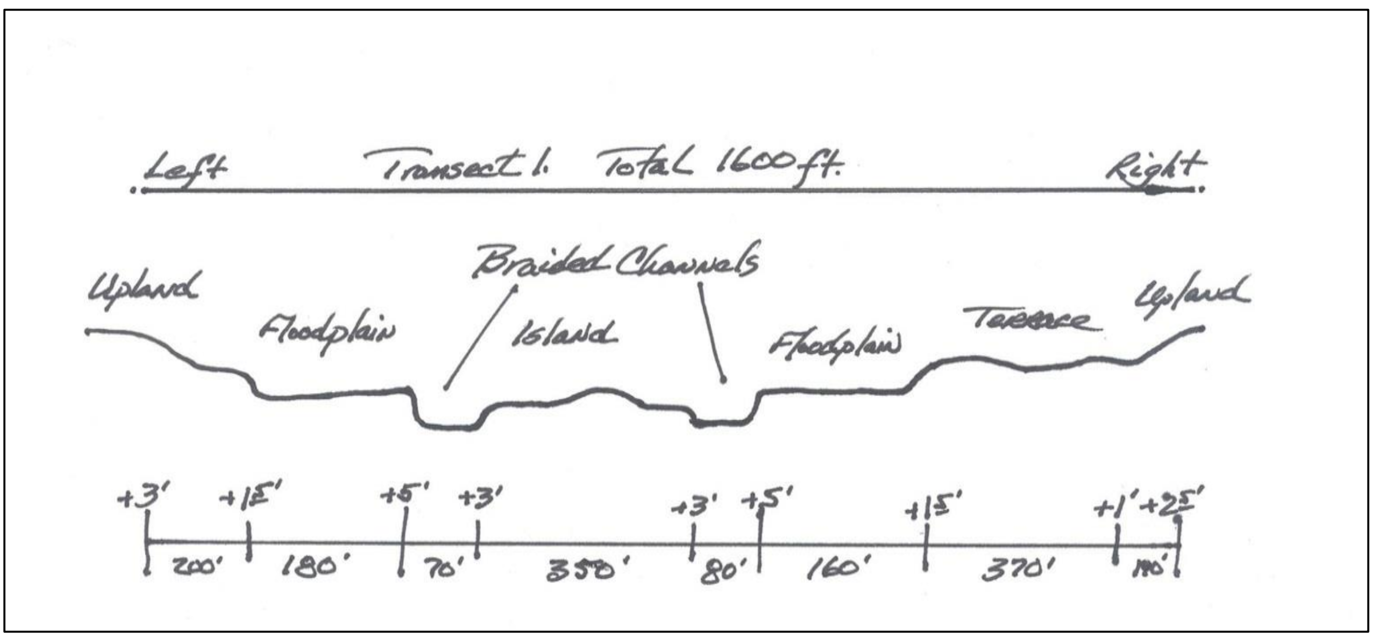


Figure 7. Representative watercourse cross-section from data sheet that identifies the fluvially active and inactive geomorphic units. Terrace on right was determined to be abandoned given the overall rounding of the surfaces, coppice dunes at base of vegetation, and red-brown soil development present at animal burrows – all indicators of fluvial inactivity.

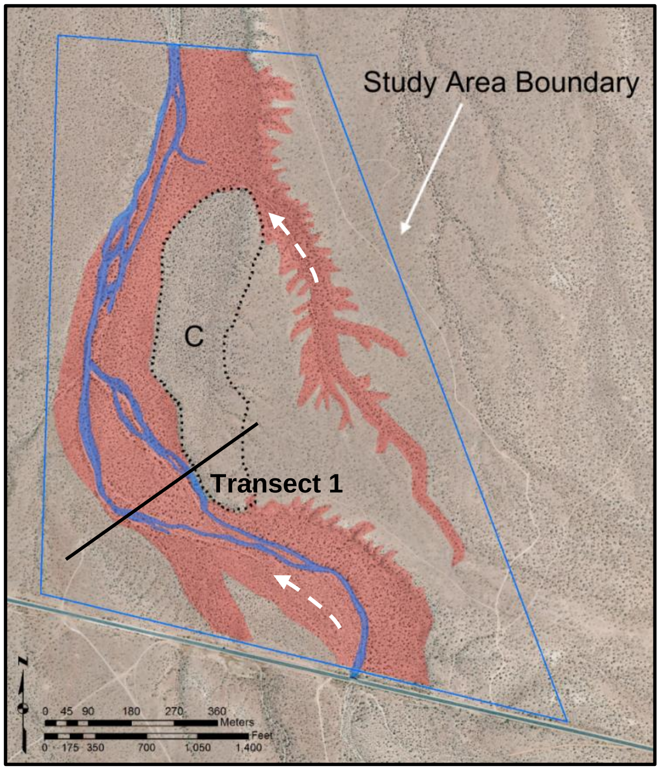


Figure 8. Watercourse Map. The field investigation found that the eastern half of Transect 1 (see also Figure 5) is dominated by terrestrial and eolian features and lacks indicators of recent fluvial activity. Landform (**C**) was interpreted to be an inactive terrace rather than an active floodplain, so was excluded from the watercourse. This delineation of the watercourse boundary was subsequently supported by the hydraulic analyses conducted for the floodplain and stormwater management plans completed as part of project development. The watercourse is shown in pink; the low flow channel, a subordinate feature lying within the watercourse boundary, is shown in blue; direction of stream flow indicated by dashed white arrows.

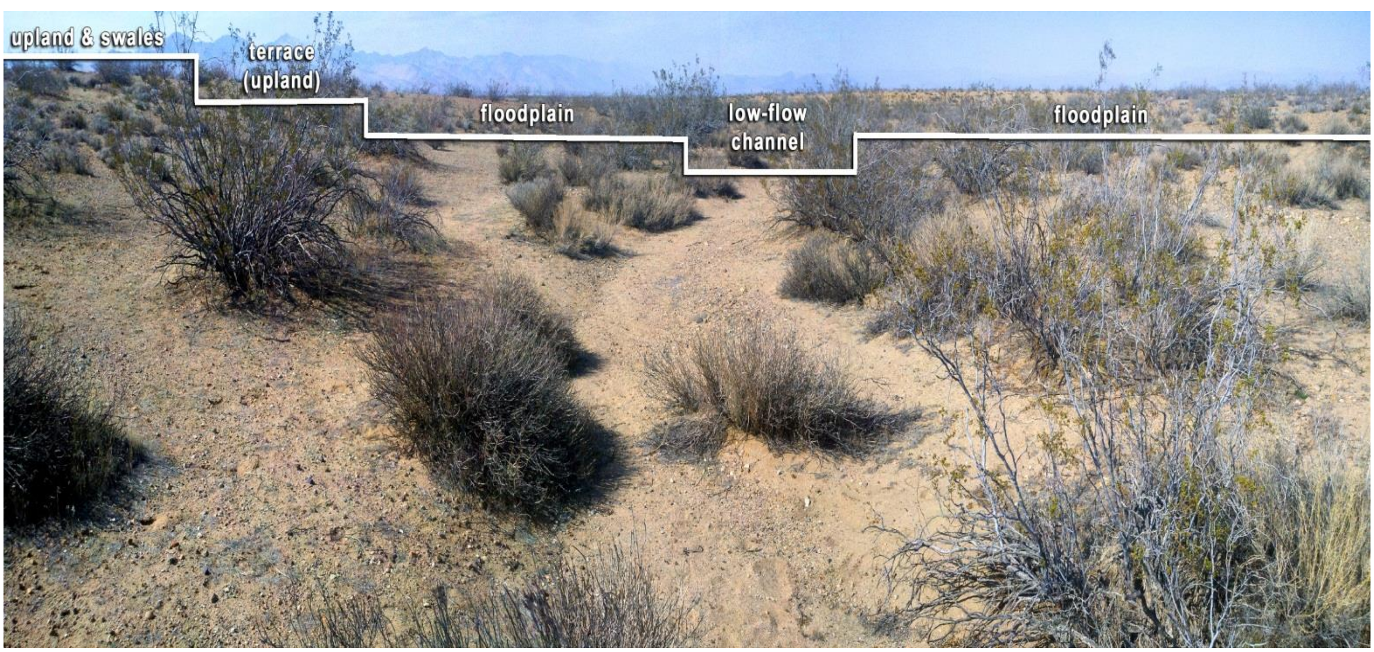


Figure 9. Representative watercourse transect that depicts the various geomorphic units and their influence on the vegetation – species diversity, vigor (size), shrub density, species abundance, and overall vegetative cover. Note the creosote bush are significantly larger and more verdant on or near the channels, providing greater cover, more flowers, seeds, and insect prey. The depauperate bursage, characteristic of the uplands, are replaced by robust desert senna and cheesebush, with occasional scale broom. Burrows (measured in percent cover) are also more abundant on the floodplains than the adjacent uplands. The uplands seen on the far left – in this case the side slopes of the ridge – are atypically dense, as are the swales that dissect the side slopes. The abundance of swales, and their role in the hydrology of the entire system, is apparent in Figure 3, and delineated in Figure 4.

1. *Jurisdictional Measures.* As with the confusion that comes with the use of colloquial terminology that has lost its scientific context, sometimes our ability to see the streams right before us is obscured by the misuse of, or misconceptions about, the measures put in place by the people of California to protect and conserve their stream resources. A list of the most common problems includes:

   Incorrect definitions: Projects often incorrectly apply the definition of a "stream" as used in Title 14, California Code of Regulations, Section 1.72 to identify streams subject to CDFW jurisdiction. This definition of a stream is not used by the CDFW in general, nor specifically in the administration of F&GC Section 1600 et sequence. The definitions currently used in practice by CDFW are those used in this *Field Guide*.

   Stream delineations based on incorrect criteria: Although there are several conditions that trigger its authority and how it is acted on, the F&GC states that *all streams (and lakes)* are subject to Section 1600 et seq. Commonly misapplied criteria like the size of a stream, the duration or size of its flow, its channel or bank form, the presence or absence of riparian or wash-dependent vegetation, the presence or absence of aquatic flora and fauna, or the quality of the habitat present are immaterial. While these attributes could certainly influence decisions about project design or how or whether to mitigate for project-related impacts, they do not define a stream relative to F&GC jurisdiction. Similarly, the type of playa (i.e. dry/hard or wet/soft) is immaterial to its jurisdictional status.

   Obsolete guidance: Projects commonly cite *A Field Guide to Lake and Streambed Alteration Agreements* as the document used to guide their stream mapping efforts (CDFW 1994). Due to its inaccuracies and unclear concepts, and more significantly the advances in the sciences of fluvial geomorphology and ecohydrology, neither this document, nor a subsequent version dated May 2000, have been in use or available from CDFW for at least a decade.

   Use of vegetation alone to map watercourse boundaries: Stream delineations based on the use of vegetation alone are a common practice. Although it can be a secondary indicator of stream presence, and reflect changes in soil moisture and substrate texture, vegetation should not be used in place of physical evidence of stream presence, or for determining watercourse boundaries. Where vegetation mapping is undertaken within project boundaries, it may complement other natural resources investigations but it cannot be relied on to determine the presence or absence of a stream or its boundaries, which are defined geomorphically and hydrologically.

   Habitat value or quality: As noted above, limits on jurisdiction based on habitat quality or value do not exist in F&GC section 1600 et sequence. Moreover, because stream channels move sediment, seeds, and organic material, as well as water, they support habitats and biological populations beyond the watercourse itself. For example, streams moving sand between headwater sources and the wind corridors that carry it to offsite dunes to maintain the physical habitat of dune-dependent species. Streams are also important dispersal pathways for many desert plants. Stream flows during summer monsoonal storms concentrate and germinate seeds in the saturated sediment at a stream terminus providing summer food for desert wildlife. These are off-site values that may equal or even exceed those present upstream, and that can be indirectly impacted by on-site activities.

Ordinary High Water (OHW): The OHW concept is not used by the State of California to determine Waters of the State, nor is it used by the CDFW to delineate stream boundaries for the purpose of determining F&GC jurisdiction. While a number of western states defer to or have adopted the federal government's approach to delineating jurisdictional waters within state boundaries, the state of California does not. Rather, the California Water Code Section 13050(e) defines the Waters of the State separately and uniquely from the federal definition as *"…any surface water or groundwater, including saline waters, within the boundaries of the state."* The state definition places no limitation on the size of stream flow as is implicitly the case for the Waters of the US.

Beneficial uses: Because the US Army Corps of Engineers determines many episodic streams not to be waters of the US for the purposes of enforcing federal Clean Water Act section 404, it is often assumed that this is the case as well for the State Water Resources Control Boards (Water Boards). This is not correct. <u>All</u> Waters of the State regardless of other designations are subject to the jurisdiction of the Water Boards. Beneficial uses are generally designated for streams and their watersheds – not just a stream or some part of the stream system. And it is the uses of the water that are designated, not the stream itself. These uses – including environmental considerations – are designated regardless of **stream order** or stream type unless specifically noted otherwise in the regional Basin Plan. For example, the Regional Water Quality Control Plan (or Basin Plan) for the Colorado River Basin designates ground water recharge and certain habitat uses as beneficial uses for many large dry wash systems in that region.

2. *<u>Related Stream Mapping Resources</u>.* Many development projects produce geologic studies, and flood and stormwater management studies, maps, and models. Developed for different end purposes, these investigations generally do not consider all aspects of the landscape relevant to the ecohydrologic function of the stream corridor and its biotic community. Nevertheless, where they are available, these geologic and flood hazard investigations should be considered in all stream delineation efforts, and vice versa. Although they may show flood boundaries in areas where no watercourse has been mapped, or no watercourse flood boundaries where ecohydrologically significant first order streams have been otherwise accounted for in a natural resource-based delineation, stormwater drainage or FEMA floodplain delineation maps may provide secondary confirmation of watercourse boundaries. They may also help discriminate between fluvially active floodplains and fluvially inactive uplands where surficial geologic evidence is subtle or absent. Similarly, geologic maps may indicate **alluvial fan** units and identify broader areas that should be included in the active watercourse, thereby informing the stream delineation process even though their scale is often too coarse to allow first-order streams to be accurately mapped (Figures 10 and 11) (AFTF 2010a; 2010b; CGS 2013; CGS 2012).

3. *<u>Vegetation Mapping</u>*. Vegetation mapping – conducted separately from the stream mapping – should only be conducted by biological specialists with the appropriate expertise. It should be based on the classification system described in the California Native Plant Society and Department of Fish and Wildlife *Manual of California Vegetation*; it is the state standard for classification and mapping, and it is consistent with the national vegetation mapping classification system (Sawyer et al 2009). Plant communities should be documented in the field using the Protocol for Combined Vegetation Rapid Assessment. The protocol, associated data sheets, and accurate vegetation map for approximately six million acres of the California desert spanning desert portions of Inyo, Kern, Los Angeles, San Bernardino, Riverside, and Imperial Counties as it pertains to renewable energy sources and conservation opportunities are available online from the CDFW Biogeographic Data portal at http://www.dfg.ca.gov/biogeodata/vegcamp/.

4. *Uplands.* Although dominated by terrestrial processes, uplands commonly include swales, and first- and sometimes higher-order streams that are essential to stream ecosystem function and should be identified (CDFW 2010). Their presence and the extent of their fluvial activity are usually more appropriately documented with a survey along their length rather than in cross section; include notes on such features, where present, on the Watercourse and (or) Upland sections of the Data Sheets.

5. *Watercourse.* The watercourse includes all functionally related swales, first-order streams, single-thread channels, compound channels, braided channels, discontinuous and distributary channel networks, and floodplains.

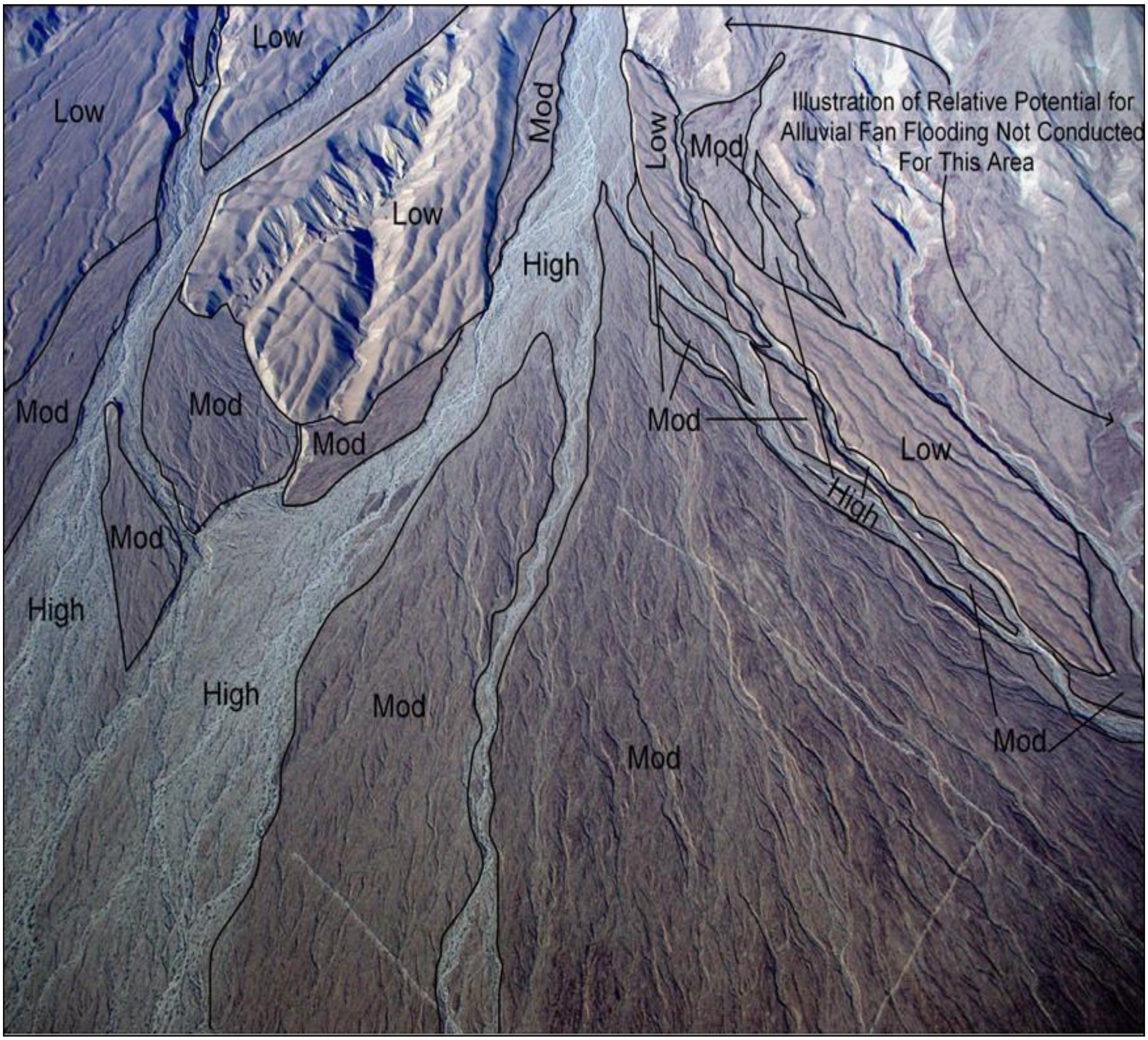


Figure 10. Alluvial Fan Relative Flood Hazards. Note the similarity between this map of active fan flood potential and the active watercourse map in Figure 8. The principal difference is that this map was developed to broadly identify areas with a high potential of flooding (the lighter colored surfaces of sharp relief) versus those with a moderate to low potential of flooding (the more rounded, darker surfaces). The lower potential surfaces likely include first- and second-order streams not shown here but that should be accounted for in a project's natural resource assessment of stream presence. Santa Rosa Mountains, Riverside County, CA. *Photograph and map courtesy of J. Lancaster, CA Geological Survey.*

6. *Secondary Channels and Floodplains.* Topographically higher secondary channels that carry water only during higher flows and floodplain overflow surfaces that occur on either side or at the terminal end of a channel lie within the bounds of a watercourse and are inextricably linked to stream and ecosystem function (Figure 11). Indicators of flow may be subtle (see *Photographic Atlas*). Document indicators on the Watercourse Indicators section of the *Data Sheet*. *Guidance on Defining Watercourse Boundaries* is included in the *Mapping Tools*.

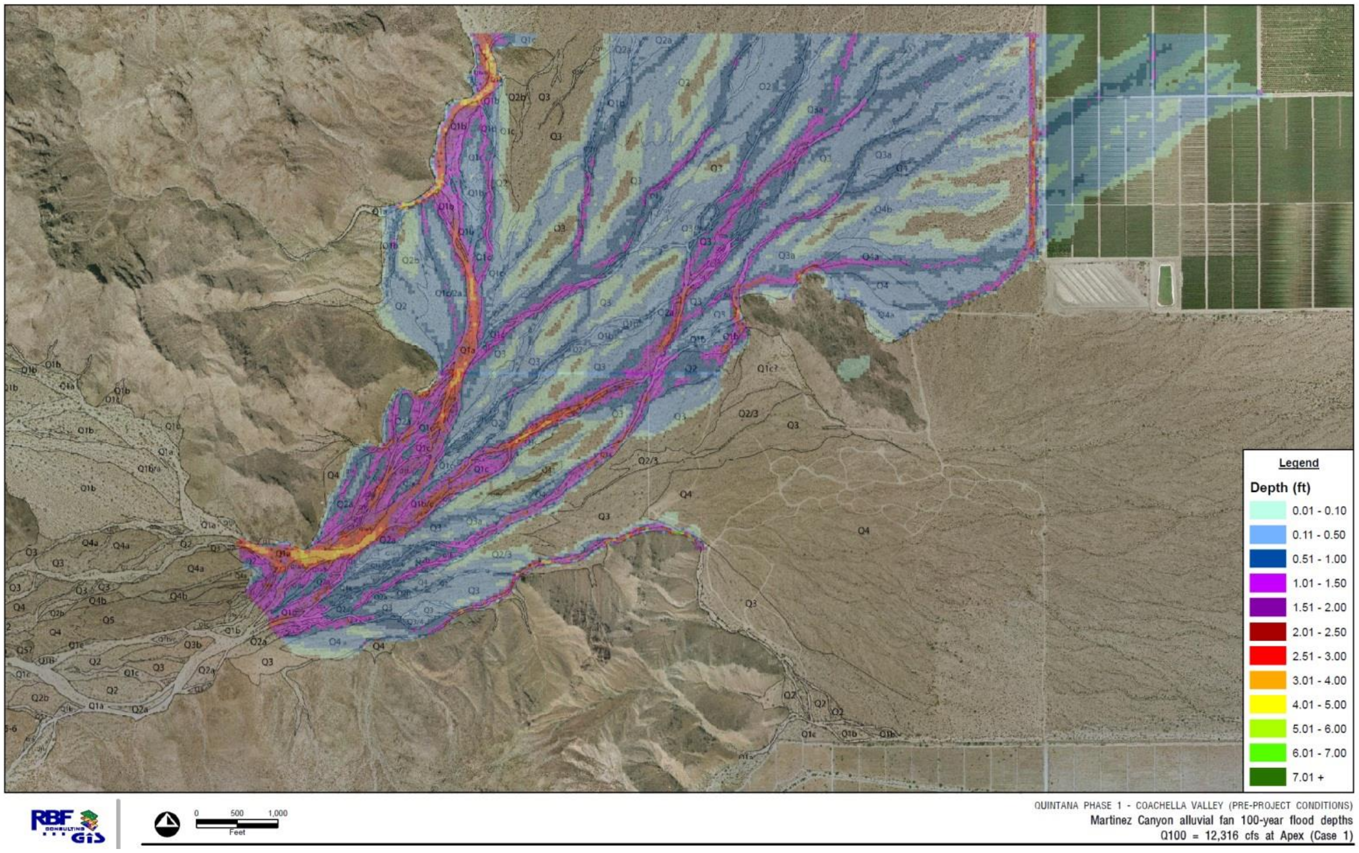


Figure 11. Distributary stream system, Martinez alluvial fan, Riverside County, CA. As a single-thread, compound, or braided stream flows from a boundary controlled reach the channel form may transition to a network of distributary channels that increase in number and decrease in width and depth as the network expands down slope. During runoff the capacity of individual channels can be exceeded and their flows coalesced into a broad expanse of shallow flooding. The red and orange colors indicate water depths of 2.5 to 4 feet; the lightest blue water depths of a 0.10 of a foot or less. These are out-of-channel flow floodplain areas and define the outermost bounds of the watercourse. *Map and Flo-2D model of distributary channel flow courtesy of JE Fuller Hydrology and Geomorphology & RBF Consultants, CA.*

7. *Islands.* These bodies of land and the unique habitat they provide are defined and generally formed by the water that surrounds, shapes, and interacts with them. Islands are part of the watercourse unless their landscapes and ecosystem characteristics are notably different from those of the watercourse, and there is minimal physical or biological exchange between them and the stream. If an island is determined to lie outside of the active watercourse, document the differences in the geomorphic indicators or vegetation characteristics and include explanatory notes in the Upland Indicators section of the *Data Sheet*.

8. *Terraces and Interfluves*. These are fluvially inactive upland landforms dominated by terrestrial (upland versus fluvial) geomorphic indicators. Include the indicators on the *Upland Indicators* section of the *Data Sheet*. If, however, indicators of fluvial activity dominate on what have been identified as "terraces" or "interfluves" they are more likely "floodplains" and as such, lie within the watercourse boundaries. Note these indicators on the *Watercourse Indicators* section of the *Data Sheet*. Also note if the vegetation characteristics on the terraces or interfluves notably differ from those on the watercourse and upland.

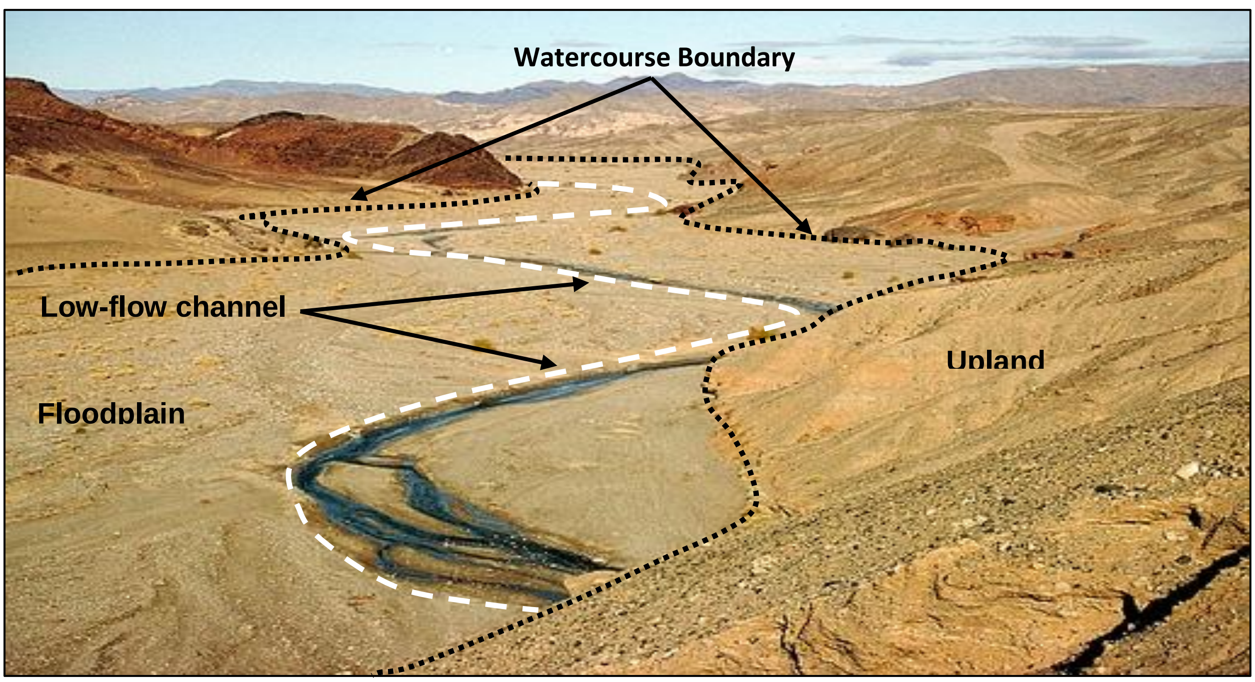
9. *Length of Stream Mapped.* For streams that enter and exit a project footprint, map the entire length of the stream within the project boundary, and at least 250 feet of stream upstream and downstream of the project boundary. Include any stream segments that exit and re-enter the project area. If development designs will eliminate stream segments by diverting their flow around the project area, the minimum length of stream to be mapped upstream and downstream of project boundaries should be determined by: 1) the site-specific diversion design including how far upstream potentially detrimental impacts to a stream are likely to occur, and 2) the site-specific design for returning flows to downstream stream segments that lie outside the project boundaries. If diversions would redirect or consolidate streams within the project area into natural stream channels outside of the project area, the receiving stream or streams should also be mapped regardless of their location relative to project boundaries in order to ensure that potentially detrimental effects are identified and avoided.

Review of Channel Forms & Geomorphic Units

A stream's channel morphology is driven in large part by the discharge patterns associated with the local hydrologic regime and the characteristics of the geologic materials across which the stream flows (*e.g.* a narrow, single-thread channel forms in bedrock-dominated reaches while a wide and braided channel forms where the stream flows through sands and gravels).

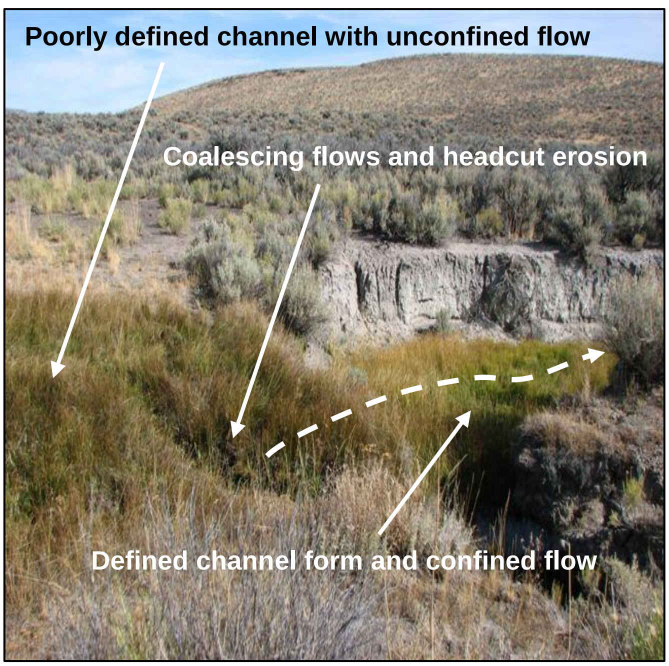
Five major channel forms characterize the episodic streams of California: single-thread channels, compound channels, braided channels, **discontinuous channels**, and distributary channels. In cross section, these channel forms are associated with an array of related geomorphic units including islands, bars, low-flow and secondary channels, and floodplains. The *Review of Channel Forms and Geomorphic Units* includes photographs and descriptions of the characteristic channel forms and geomorphic units that collectively define a watercourse. In addition, examples of fluvially inactive units are reviewed, including uplands, terraces, and abandoned channels.

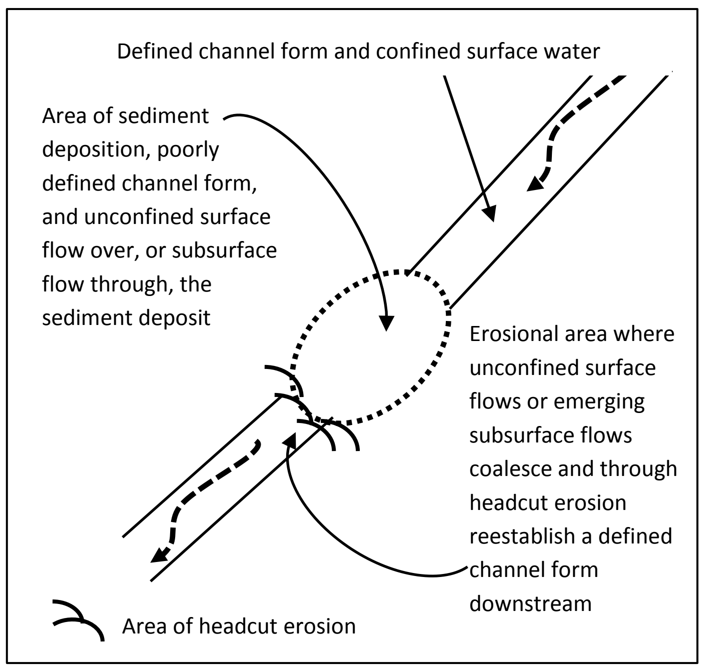
Single-thread channel. Flow is restricted to a single, discrete channel. Ephemeral, single-thread channels tend to be shorter, more numerous, have a lower sinuosity than temperate-region streams, and are generally first- or second-order tributaries that flow to larger, main stem channels (Schumm 1961). Tributary to the Amargosa River, Sheep Creek Fan, Avawatz Mountains in background, San Bernardino County, California.



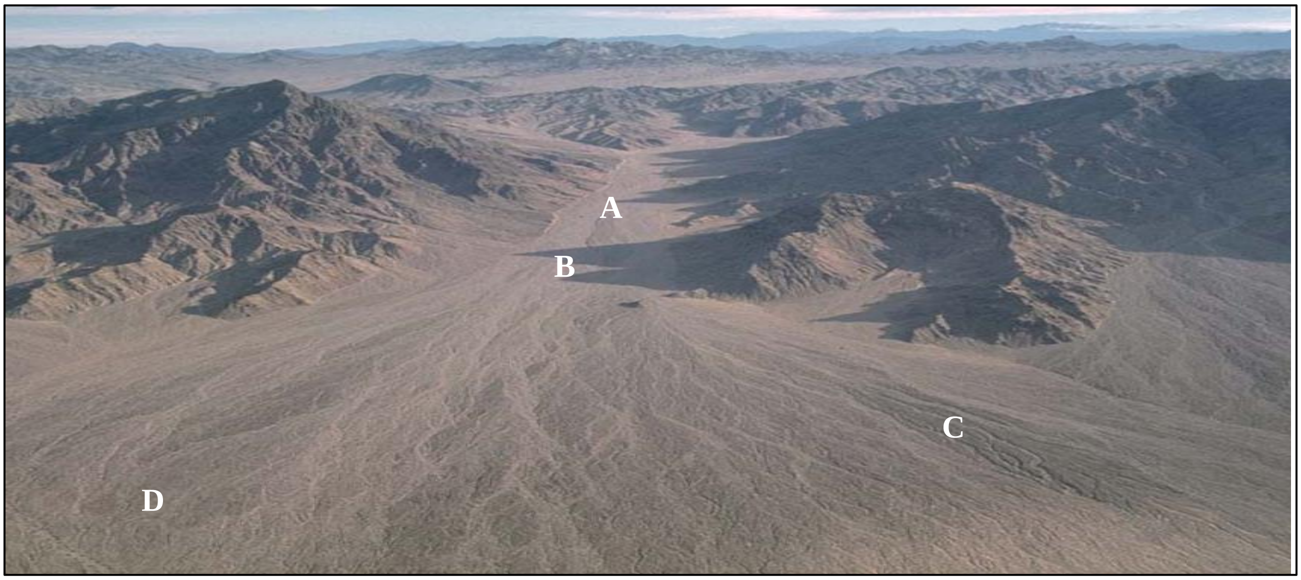
Compound channel: The most common channel form for larger streams in dryland regions, compound channels are characterized by a single, **meandering**, low-flow channel nested within a larger watercourse defined by a frequently shifting, channel network (Graf 1988; Tooth 2000). The low-flow channels are susceptible to widening and **avulsion** during moderate to high discharges, re-establishing as smaller channels during declining flows or subsequent low-flow events. Amargosa River, San Bernardino County, California. *Photo courtesy of Marli Bryant Miller, www.marlimillerphoto.com*

Braided channel: Multiple active channels that divide and rejoin to form a pattern of gently curved channel segments separated by exposed ephemeral islands or channel bars. Even when external conditions are constant, the braided pattern is continually changing. Lytle Creek, San Bernardino County, CA. *Photo: Google Earth, 2013.*

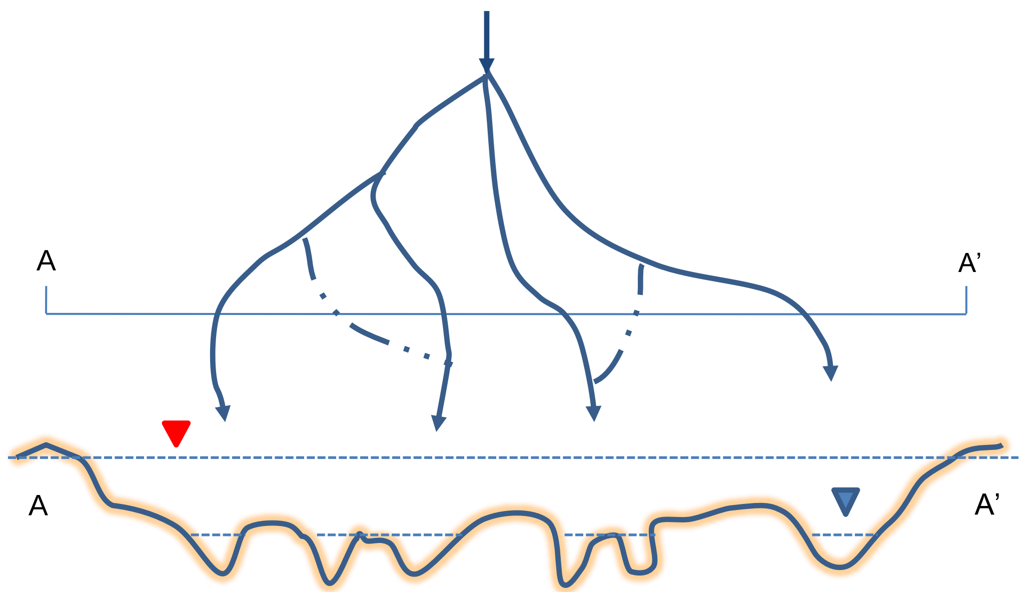




Discontinuous channel: These streams form a distinctive pattern of well-defined erosional channel segments that alternate with depositional reaches having poorly defined channel form and unconfined or subsurface flow. The changes in fluvial processes from deposition to erosion cause periodic loss and recovery of a defined channel form. Channel form becomes less defined or is lost altogether as stream flow declines and sediment is deposited. With subsequent runoff, surface flow through depositional reaches is unconfined or lost when flow infiltrates into the stream bed, moving through the subsurface until it reemerges in better defined channel segments downstream. Where surface water connectivity is reestablished a cycle of headcut erosion is initiated that re-concentrates the flow again into a single, defined channel. Changing channel morphology is the defining characteristic of the discontinuous stream (Bull 1997; Field 2001). High Rock Desert, Nevada. *Photo: K. Vyverberg, CDFW*.



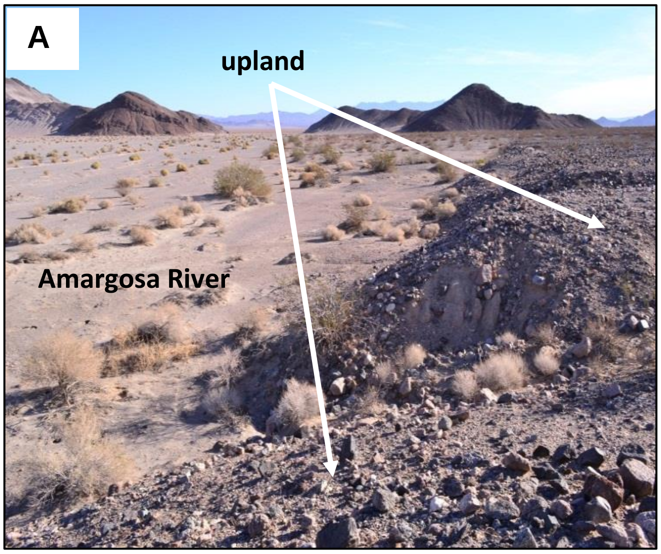
Distributary channel network. In contrast to tributary channels that decrease in number as they converge toward a main channel, distributary channels diverge, increasing in number and decreasing in size toward their terminus. In the photo, a compound stream channel emerges from the mountains at the fan apex (A) then splits into a network of distributary watercourses (B). These distributary channels are separated by drainage divides formed by dissection of older fan deposits (C), shown by their darkened varnish. As a stream flows down the fan, its channels decrease in width and depth and lose definition. The reduced channel width, depth, and gradient can force water to overtop the banks of individual channels and combine with overflow from adjacent channels to coalesce into a thin, relatively uniform expanse of water. This shallow flooding is superficially similar to overland flow and sheetflooding, but is here recognized as a distinct flood phase that occurs when the capacity of small, individual channels within a broader watercourse is exceeded and the overflow onto floodplains coalesce. This shallow, out-of-channel flooding is analogous to floods that overtop stream banks and inundate temperate region floodplains, and is a process that may dominate the lower fan apron (D) and alluvial plains. Death Valley, California. *Photo courtesy of Marli Bryant Miller, www.marlimillerphoto.com.*

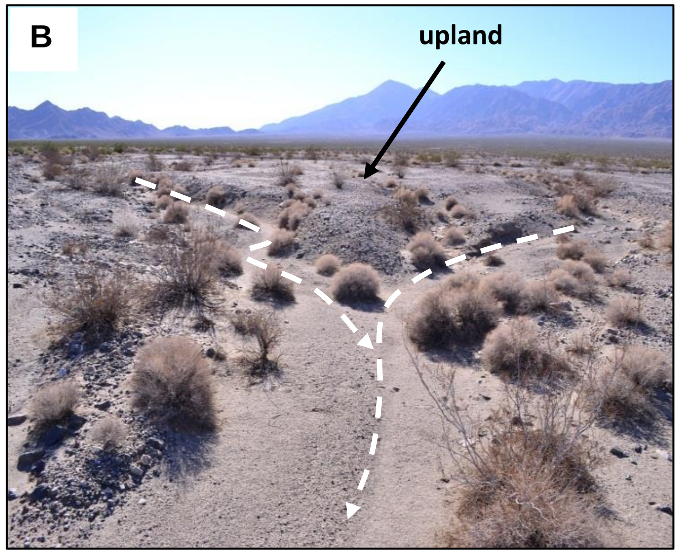


Cross section A-A’

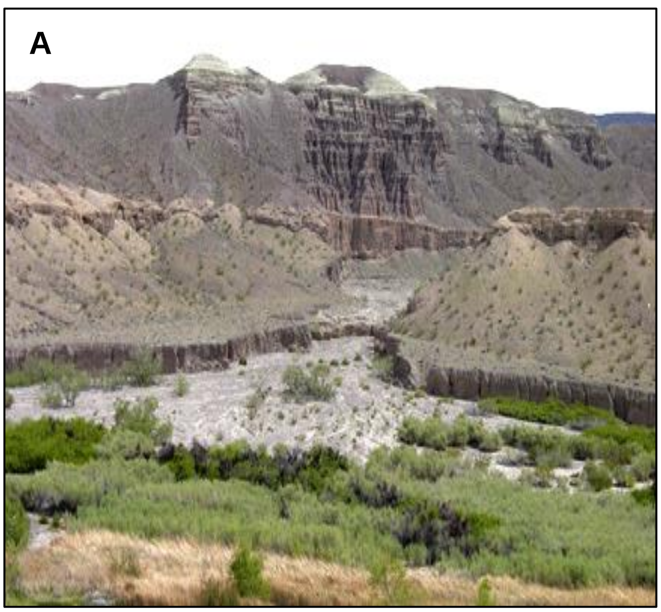
In-channel flow water

Out-of-channel flood water surface results from flows that overtop individual channels and coalesce to inundate lateral and terminal floodplain areas. The result is a broad area of flood flow that defines the outer bounds of the distributary channel watercourse.

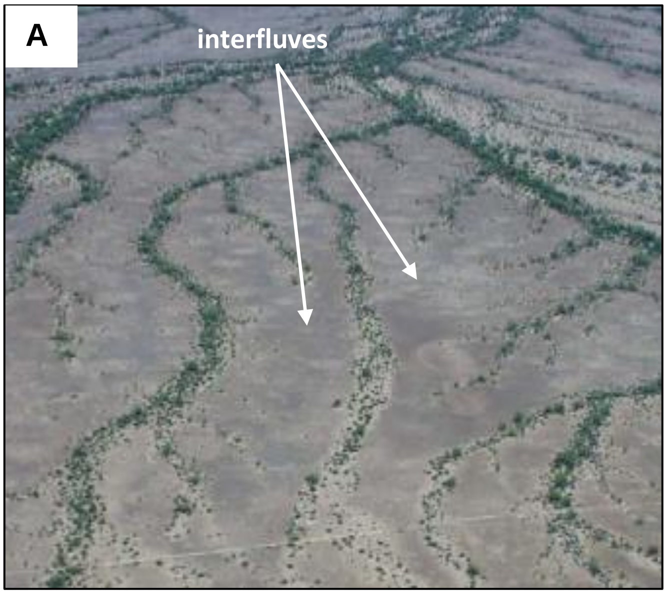


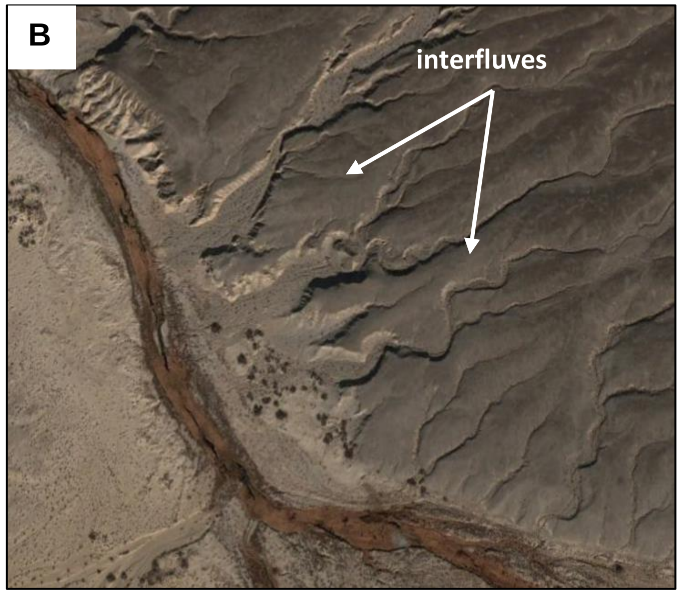


Upland. Photo A: distal end of Sheep Creek Fan at its terminus with the Amargosa River, southern Death Valley, San Bernardino County. Photo B: upland above confluence of two tributaries to the Amargosa River. Sheep Creek Fan, southern Death Valley, San Bernardino County, California.

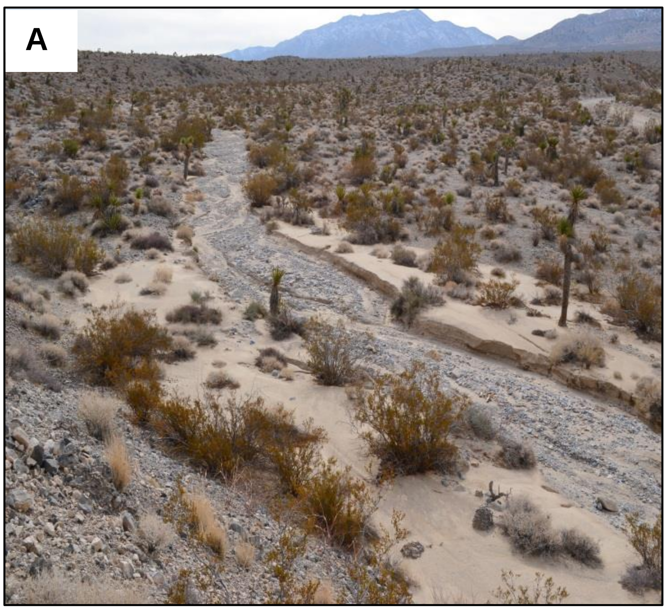


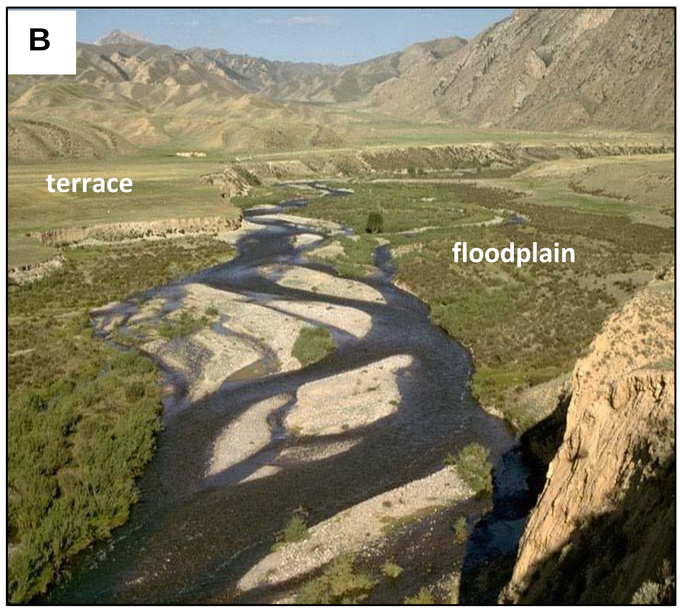
Terrace. Photo A: cross-sectional view of paired terraces, tributary to the Mojave River, Afton Canyon, San Bernardino County, California. Photo B: Caliche-cemented gravels (pale zone topped by a ledge) form the resistant cap rock of older Pleistocene terrace surfaces along the sides of the modern wash. In the distance, the surface of an older Quaternary alluvial fan is preserved intact. Providence Mountains in the distance, San Bernardino County, California. *Photos: US Geological Survey*.



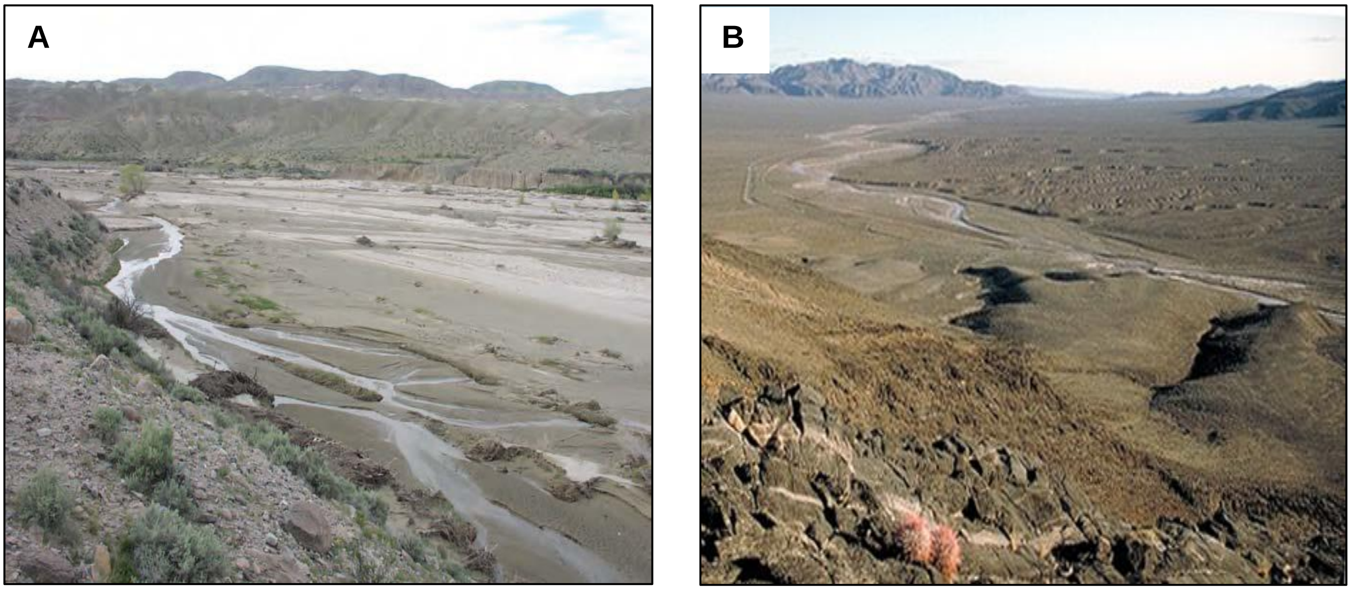


Interfluves. An interfluve is a relatively undissected upland between two adjacent stream channels in the same drainage network. Photo A: Lower Colorado River region, Sonoran Desert, McDonald et al. 2004. Photo B: Tributary streams to the Amargosa River, Southern Death Valley, California. *Photo: Google Earth, 2013.*

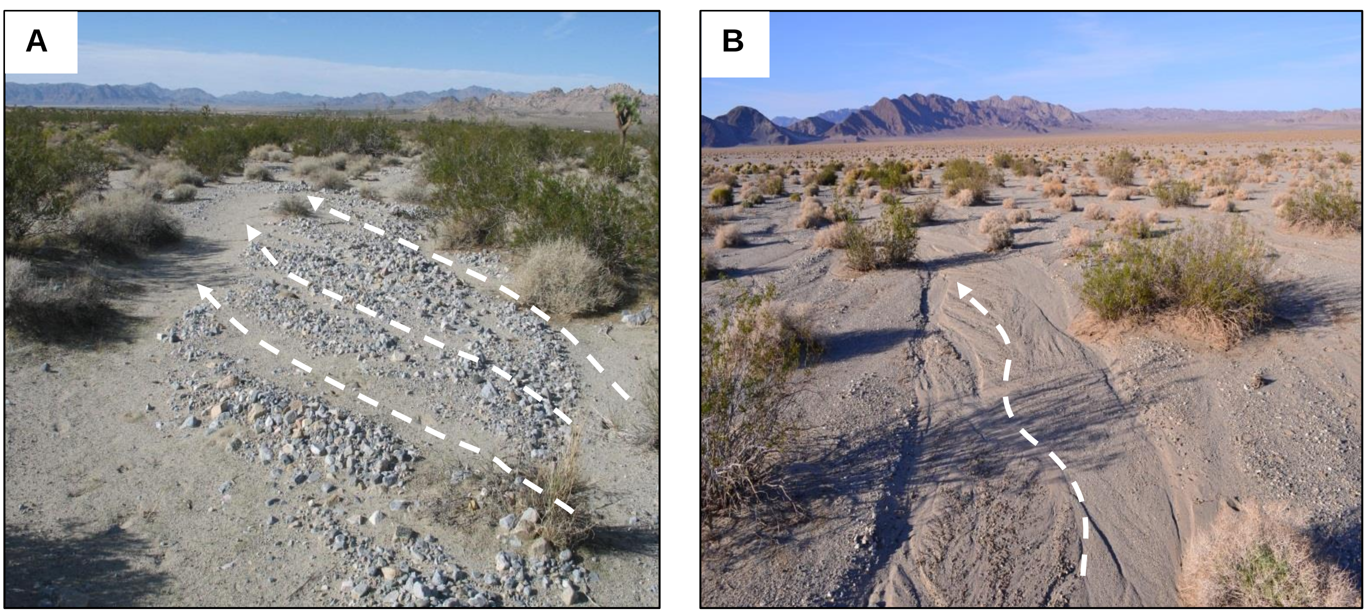




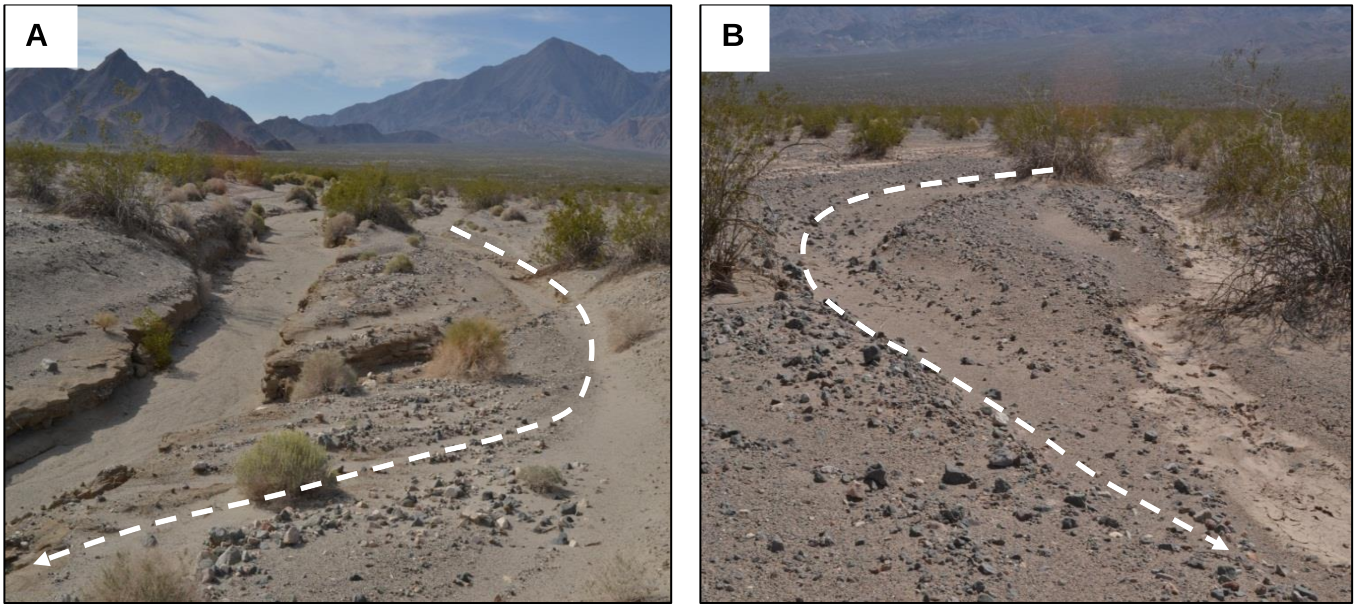
Floodplain. The floodplain area in Photo A is defined by light colored, out-of-channel flow deposits of fine grained sediment that contrasts with the coarse grained and darker upland surface. The active floodplain in Photo B is inset between terraces (i.e. abandoned floodplain). Floodplains are linked to stream and ecosystem function and lie within the bounds of the watercourse. Photo A: Lucerne Valley, San Bernardino County, California. Photo B: Son-Kul River, Kyrgyzstan, Central Asia. *Photo courtesy of Marli Bryant Miller, www.marlimillerphoto.com*



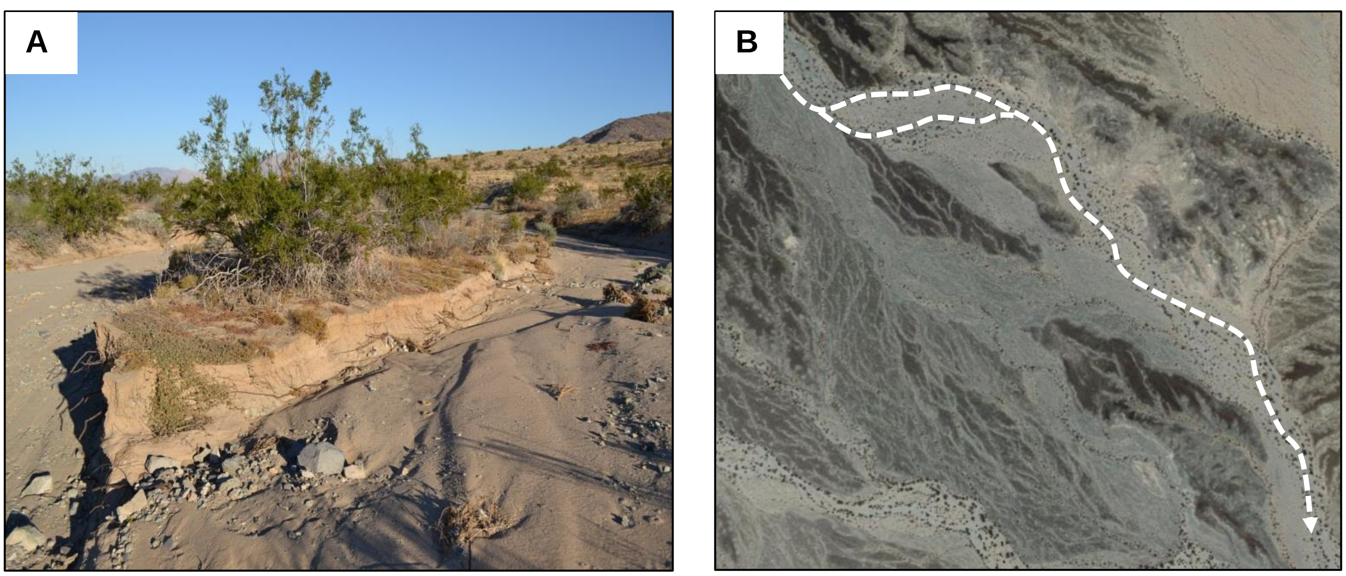
Low-flow channel. A low-flow channel is the dominant subchannel nested within the transient braided channel network of the larger watercourse of a compound channel. When flow exceeds the capacity of the low-flow channel, the subdominant network of braided channels begin to flow. When the capacity of these channels is exceeded, flow extends across the watercourse and the bed materials of all channels are mobilized. As high flows recede, a new low-flow channel is formed. Photo A: Mojave River, San Bernardino County, California, Lichvar and McColley 2008. Photo B: Amargosa River, San Bernardino County, California. *Photo courtesy of Marli Bryant Miller, www.marlimillerphoto.com*



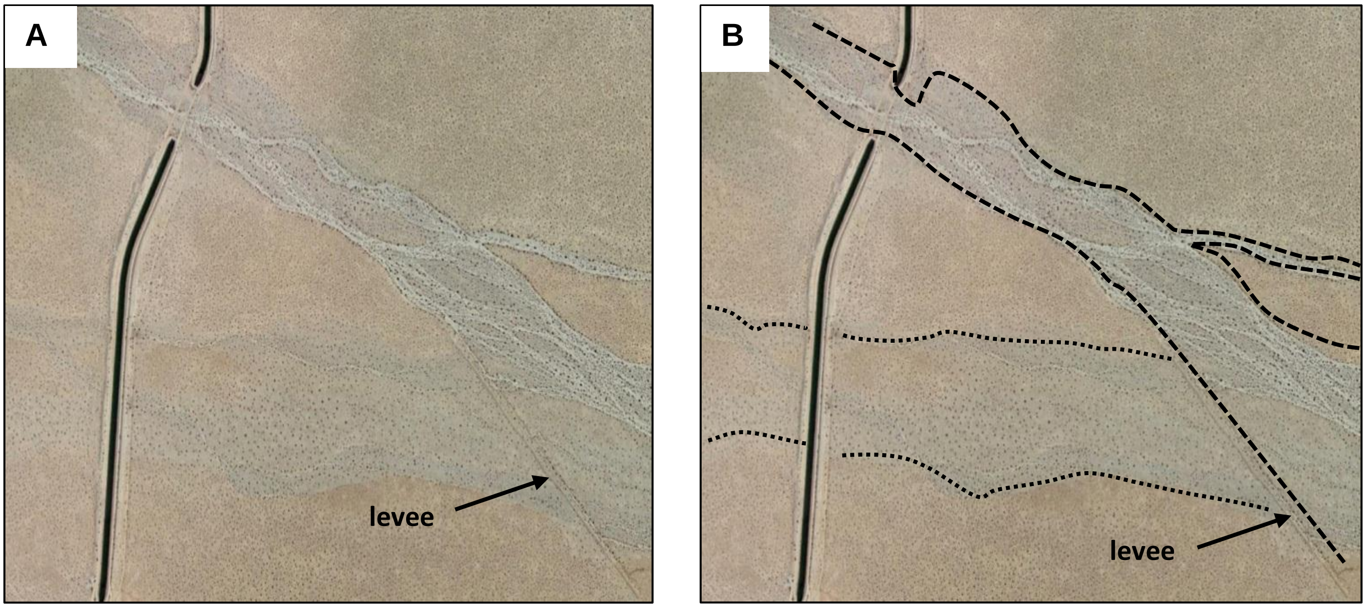
Bars. Bars are ridge-like accumulations of sand or gravel deposited along the bed or bank of a stream channel, or at the confluence of one stream with another where decreased water velocity induces deposition. Photo A: mid-channel gravel bar, Lucerne Valley, San Bernardino County, California. Photo B: mid-channel sand bar, distal edge of Sheep Creek Fan, southern Death Valley, San Bernardino County, California.



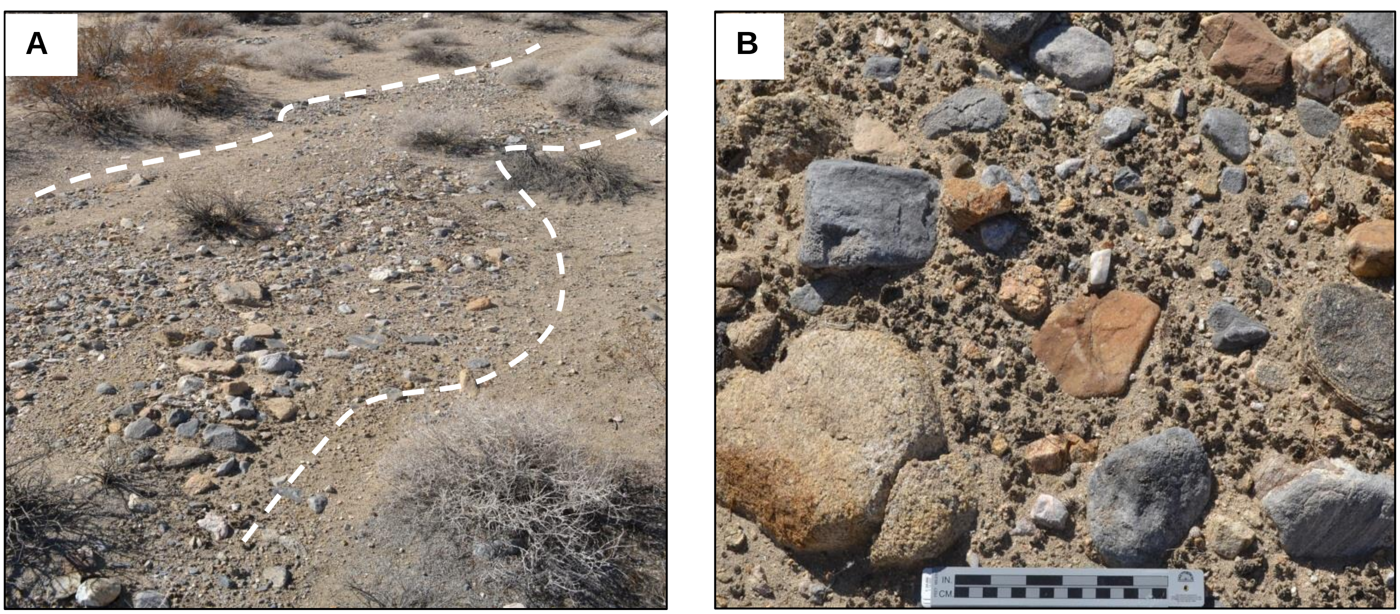
Secondary channels. A stream can have a primary channel that conveys most flow and one or more topographically higher channels of varying sizes that carry water only during higher or flood flows. Sometimes referred to as "high-flow" channels, these features are essential to stream and ecosystem function, allowing the system to accommodate rising flood waters while reducing erosion to the bed and banks of the main channel. Secondary channels are a transition zone between the stream and upland environment that provide varied water depths and velocities, changes in sediment transport and deposition, and temporal and spatial variations in the extent and period of inundation and saturation that combine to increase habitat diversity and complexity. Photo A: Salt Creek, Death Valley, San Bernardino County, California. Photo B: Pipeline Wash, Avawatz Mountains, southern Death Valley, San Bernardino County, California.



Islands. Islands are considered separately from their watercourse only if their landscape and ecosystem function differ from the watercourse, and the physical and biological exchange between them is minimal. Photo A: Island size, cut banks and exposed roots indicate active exchange between stream and island. Pinto Mountains, Riverside County, CA. Photo B: The dark brown "islands" in photo center have a well-developed surface of rock varnish, and are separated from the active channel and surrounded by younger fluvial deposits that have begun to darken with age, both surfaces suggesting fluvial inactivity and that the "islands" might reasonably be excluded from the watercourse, Mule Mountains, Riverside County, CA. *Photo B: Google Earth, 2013.*



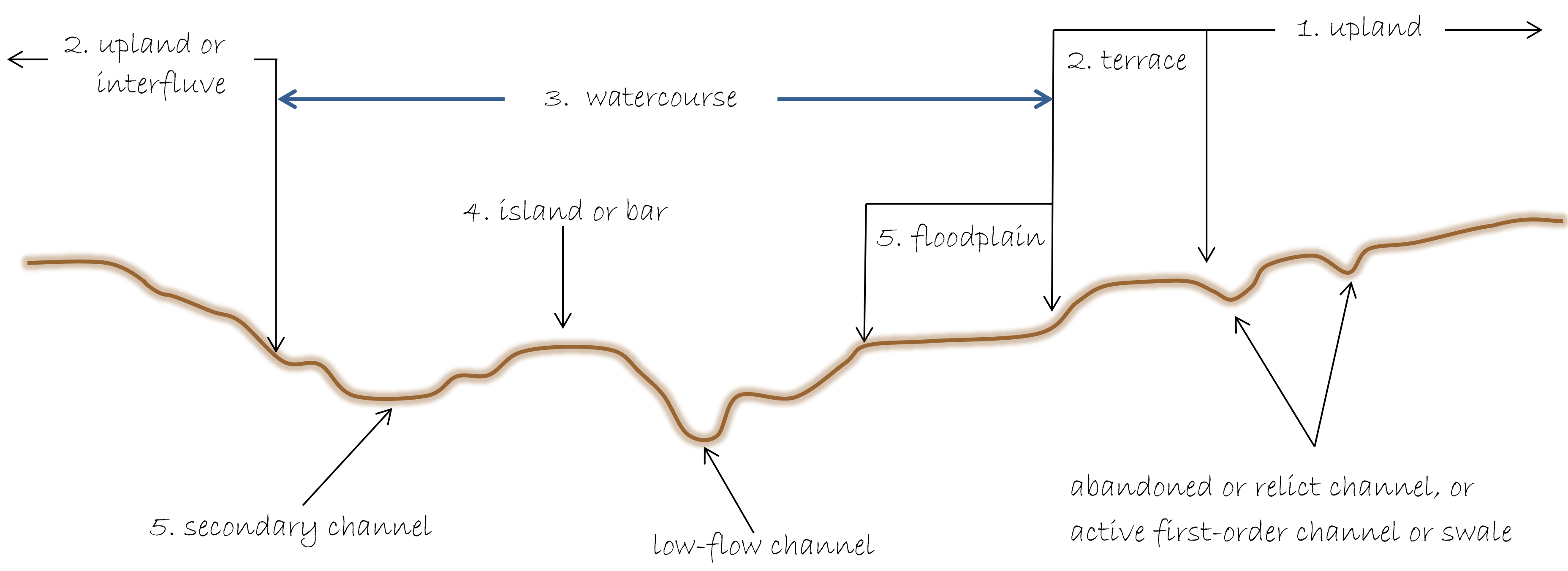
Abandoned channel. A watercourse along which stream flow can no longer occur. For example, a channel isolated from its water source through fault activity, the diversion of the headwater of one stream into the channel of another stream having greater erosional activity, or by human constructs such as levees – as in this example. The dark line on the left side of both photos is the Colorado Aqueduct. An abandoned wash segment defined by the black dotted line in Photo B is isolated between the levee and the aqueduct. Its flow upstream of the levee is redirected into a wash (defined by dashed black lines) crosses over the aqueduct. With time and the cessation of the processes responsible for its formation, an abandoned channel will become a relict channel. Colorado Aqueduct, San Bernardino County, California. Google Earth, 2013.



Relict Channel. A channel made by processes no longer locally active and showing signs of age. The absence of recent fluvial erosion and deposition is shown here by in-place weathering; rock fracturing; weak rubification of surface gravels underlain by an incipient vesicular A horizon, and well-developed and widespread biological soil crusts (Photo Atlas, page 6-5) – collectively indicative of at least many hundreds of years of fluvial inactivity.
Lucerne Valley, San Bernardino County, California.

MAPPING TOOLS

Representative Watercourse Cross Section with Associated Geomorphic Units



Guidance on Defining Watercourse Boundaries

1. **Uplands:** although dominated by terrestrial processes, uplands commonly include drainage swales and first- and sometimes higher-order streams. Document the presence and fluvial activity of these with a separate longitudinal survey using both the Watercourse and Upland indicators section of the Data Sheet.
2. **Terraces and interfluves:** are upland landforms. If the differences between terrace or interfluve and upland surface indicators are nominal and terrestrial indicators dominate, include their indicators on the Upland Indicators section of the Data Sheet. If the surfaces of terraces or interfluves have indicators of fluvial activity, reconsider the landform interpretation as floodplain within the watercourse boundaries, and include these indicators on the Watercourse Indicators section of the Data Sheet. If the surfaces or the percent cover and vigor of the vegetation on the terraces or interfluves notably differ from those on the adjacent upland, describe these differences in the notes to the vegetation sections of the Data Sheet.
3. **Watercourse:** includes all functionally related swales, single-thread channels, compound channels, braided channels, discontinuous and distributary channel networks, islands, and floodplains.
4. **Islands:** these bodies of land and the unique habitat they provide are defined and often formed by the water that surrounds and interacts with them. They are part of the watercourse unless their landscapes and ecosystem characteristics differ from those of the watercourse, and there is minimal physical or biological exchange between them and the stream. Document differences in surface indicators or vegetation on the Upland Indicators section of the Data Sheet and in explanatory notes.
5. **Floodplains and secondary channels:** lie within the bounds of a watercourse, and are essential to stream and ecosystem function. Include their indicators with those of the Watercourse Indicators section of the Data Sheet.

Annotated Definitions of Stream and Terrestrial Landforms	
Abandoned channel	a channel along which stream flow no longer occurs; e.g. a channel isolated from its water source through faulting or stream capture, or by human constructs such as levees. With time and the absence of the processes responsible for its formation an abandoned channel will become relict.
Active channel	a channel receiving frequent enough flow to have physical or biological evidence of fluvial activity roughly within the last 200 years before the present.
Alluvial fan	a gently sloping, fan-shaped landform that forms where steep, confined, mountain streams flow out onto a plain or valley.
Bank	the land on the outermost edge of a stream that confines or otherwise defines the stream's boundary when its waters rise to the highest level of confinement.
Bar	a ridge-like accumulation of sand or gravel formed in the channel, along the banks, at the mouth, or within the channel of a stream where a decrease in velocity induces deposition.
Channel	a defined course along which water flows perennially or episodically. Channels may be active during every runoff event or spatially or temporally dormant elements within a larger watercourse that receive water periodically during higher flows.
Dormant channel	a channel isolated from its principal water source by natural causes or human constructs such as roads, but that retains its potential for hydrologic reactivation and stream function.
Floodplain	a relatively flat area of land associated with a stream and over which water and soil from the parent stream flows when the capacity of channel is exceeded. Floodplains parallel stream channels by may also occur at the terminal end of a stream where it joins a larger wash, transitions into a playa, or the channel ends and flow subsides into the ground.
Interfluve	a relatively undissected and fluvially inactive higher ground (or upland) between two adjacent stream channels that flow in the same general direction in the same drainage network.
Island	elevated body of land periodically surrounded by and isolated from the upland landscape by water. Islands are part of a watercourse unless their landscape and ecosystem characteristics differ from those of the watercourse, and there is minimal physical and biological exchange between the two.
Low-flow channel	the topographically lowest stream channel or the dominant subchannel within a compound channel watercourse.
Relict channel	an "old" channel made by processes no longer locally operative; e.g. a stream that once drained a lake that is now permanently dry. Antiquity may be demonstrated by the presence of rock varnish, soil development, rock weathering, and the absence of recent fluvial activity.
Secondary channel	topographically higher channels that carry water only during higher flows. Also known as overflow or high flow channels.
Stream	a body of water that flows perennially or episodically during the historic hydrologic regime (ca. 1800 to present), and where the width of its course can reasonably be identified by resultant landforms or other physical and biological indicators.
Swale	a depression where runoff from the surrounding uplands concentrates to initiate stream flow; source areas considered Integral to stream function.
Terrace	planar surfaces representing infrequently or rarely flooded remnants of former floodplain.
Upland	the higher ground dominated by terrestrial processes above a watercourse.
Watercourse	the area within and along which water flows perennially or episodically through one or more channels. Where present, swales, single-thread channels, compound channels, braided channels, discontinuous and distributary channel networks, and floodplains may all occur within the bounds of a single larger channel designated the "watercourse" to discriminate between it and functionally related but subordinate fluvial landforms that lie within its bounds.

Episodic Stream Indicator Data Sheet								page 1 of 4
Site ID:	Stream ID:						Date:	
Nearest Town:				County:				
Investigators:								
Base Map								
Aerial Photo #:	Date:	Topographic Map Name:						Date:
GPS Data								
GPS Name:	Datum:	Transect Elevation:		Zone 10 / 11	GPS Error: ± ft / m			
GPS co-ords start of transect:			GPS co-ords end of transect:					
Geomorphic Province (✓one)		Mojave		Sonoran/Colorado		Great Basin	Other:	

Landform (✓ all that apply)													
	Headwater		Upper fan		Middle fan		Lower fan		Alluvial plain		Axial valley		Playa

Channel Form (✓ one)										
	Single thread		Braided		Compound		Distributary		Discontinuous	Other:

Transect was selected to:			
	Document fluvial activity & boundaries		Document channel elevations & boundaries
	Document habitat associations		Document a change in watercourse morphology
	Other:		
Date of most recent runoff event (if known):			

Physical Setting: Briefly describe geomorphic processes and surficial materials and conditions, including the degree of disturbance relative to an intact dryland stream ecosystem, and any anthropogenic influences on the channel form and function:

Summary Site Description and Cross-section Sketch: View across the channel from watercourse-edge to watercourse-edge. Identify channel(s), banks, islands, interfluves, floodplains, terraces, and uplands where present. Note approximate width and elevation differences between features indicated.

Left ____ Right

Site ID:	Stream ID:	

Note presence or absence of each indicator within a minimum distance of 50 feet upstream and 50 feet downstream of the representative channel cross section. Mark each box with a plus (**+**) for those indicators observed, and a minus (**–**) for indicators not observed. For examples see the Photo Atlas in MESA ~ Mapping Episodic Stream Indicators.

UPLAND

	Terrestrial Indicators				**Substrate Particle Size**	
					Estimated percentages	
	Av soil horizon		Relict bars & swales			
	Biotic soil crusts		Rock fractured in place		% Bedrock / Cemented substrate	
	Bioturbation		Rock varnish		% Boulder	≥ 256 mm
	Caliche: coatings / layers / rubble		Rock weathering		% Cobble	≥ 64 – 256mm
	Carbonate etching		Rubified rock undersides		% Pebble	≥ 4 – 64 mm
	Coppice dunes: active / relict		Soil development		% Granule	≥ 2 – 4 mm
	Deflated surface		Surface rounding of landform		% Sand	≤ 2 mm
	Pavement		Woody debris in place		% Silt/Clay	Fines
	Other:					

Fluvial Indicators

	Bars: sand / gravel		Mud: cracks / curls / drapes		Sediment tails: sand / gravel
	Cut banks		Organic drift		Vegetation-channel alignment
	Drainage swales		Overturned rocks		Water-cut benches
	Exposed roots		Scour		Wrack
	First-order streams		Sediment ramps: sand / gravel		Wrinkle marks
	Flow lineations		Sediment sorting		
	Other:				

Vegetation

Estimated % total vegetative cover (perennial & shrub species combined):	Dominant and co-dominant species (if known) and % of total vegetative cover of each:	Representative height and width of dominant and co-dominant species:

Differences in total shrub/perennial density (total #shrubs/perennial plants) between upland & fluvially active units or watercourse complex? (describe and qualify the differences):

Are there plant species that are present in (or absent from) the uplands when compared to fluvially active units or the watercourse complex? (describe differences):

Are there plant species that are more abundant (or less abundant) in the uplands when compared to the fluvially active units or the watercourse complex? (describe and qualify differences)

Site ID:	Stream ID:	page 3 of 4

Note presence or absence of each indicator within a minimum distance of 50 feet upstream and 50 feet downstream of a representative channel cross section. Mark each box with a plus (**+**) for those indicators observed, and a minus (**–**) for those not observed. For examples see the Photo Atlas in MESA ~ Mapping Episodic Stream Indicators.

WATERCOURSE or WATERCOURSE COMPLEX

	Transportation, Deposition & Flow Transition Indicators				**Substrate Particle Size**	
					Estimated percentages	
	Bar forms: sand / gravel		Secondary channels			
	Bifurcated flow		Sediment plastering		% Bedrock / Cemented substrate	
	Drainage swales		Sediment ramps: sand / gravel		% Boulder	≥ 256 mm
	Flow lineations		Sediment sheets: sand / gravel		% Cobble	≥ 64 – 256 mm
	Imbricated gravel		Sediment sorting		% Pebble	≥ 4 – 64 mm
	Levee ridges: sand / gravel		Sediment tails: sand / gravel		% Granule	≥ 2 – 4 mm
	Mud: cracks / curls / drapes		Vegetation-channel alignments		% Sand	≤ 2 mm
	Organic drift		Wrack		% Silt/Clay	Fines
	Overturned rocks		Wrinkle marks			
	Out-of-channel flow: Lateral floodplain / Terminal floodplain					
	Ripples					
	Other:					

Erosion Indicators

	Cut banks		Rills		Water-cut benches
	Exposed roots		Scour		Water level mark
	Headcuts		Secondary channels		
	Other:				

Vegetation

Estimated % total vegetative cover (perennial & shrub species combined):	Dominant and co-dominant species (if known) and % of total vegetative cover of each:	Representative height and width of dominant and co-dominant species:

Differences in total shrub/perennial density (total #shrubs/perennial plants) between the low-flow channel(s) and the adjacent floodplain? (describe and qualify the differences):

Are there plant species that are present in (or absent from) the low-flow channel(s) when compared to the adjacent floodplain? (describe differences):

Are there plant species that are more abundant (or less abundant) on the low-flow channel(s) and the adjacent floodplain? (describe and qualify differences)

Site ID	Stream ID	page 4 of 4

INDICATORS of PONDING & EVAPORATION and EOLIAN TRANSPORT & DEPOSITION					
	Algal crusts		Sand-filled channels		
	Beach ridges		Springs		
	Coppice dunes: active / relict		Substrate staining		
	Crusts: carbonate / salt / soda		Vegetation-landscape alignments		
	Mud: cracks / curls / polygons				
	Other:				

Additional Diagrams and Notes

Vegetation cross-section diagram: Draw a cross-section that identifies the approximate locations along the transect or diagram of geomorphic units (see page 1 of data sheet) where there are changes in vegetation characteristics, as summarized in the vegetation subsections under “Upland” and “Watercourse Complex”.

Photographs

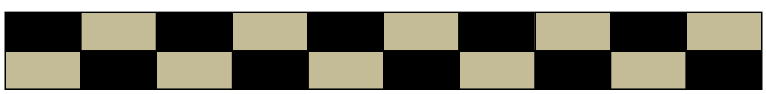
Photographs should document the representative landscape units, vegetation, and the presence or absence of representative stream indicators.

Photo ID #	Description	GPS location	

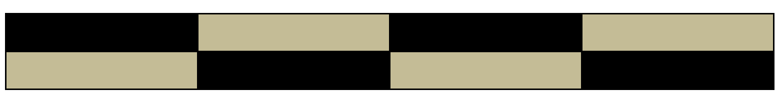
Particle Size Gradations

Description of particle size			millimeters
Boulder	mammoth		4096
	very large		2048
	large		1024
	medium		512
	small		**256**
Cobble	large		128
	small		**64**
Gravel	very coarse	Pebble	32
	coarse		16
	medium		8
	fine		4
	very fine	Granule	**2**
Sand	very coarse		1
	coarse		0.500
	medium		0.250
	fine		0.125
	very fine		**0.063**
Silt			**0.004**
Clay			

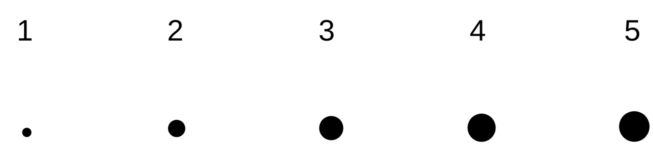
Centimeters



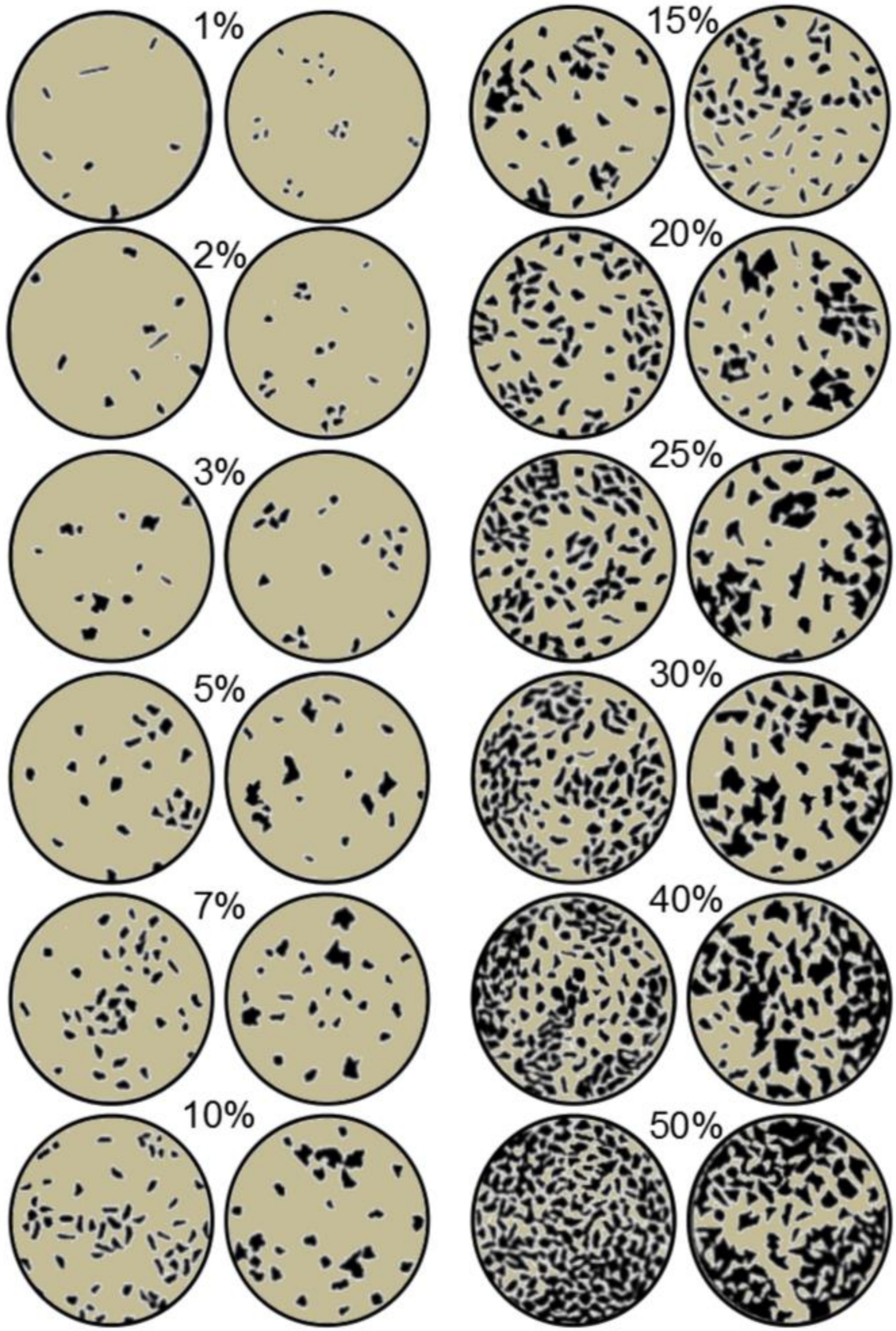
Inches



Grain Size Scale (mm)



Percent Landscape Cover Diagram



PHOTOGRAPHIC ATLAS

INDICATORS OF EPISODIC STREAM ACTIVITY

Index to Indicators of Episodic Stream Activity

Index to Indicators of Episodic Stream Activity

Explanation of Indicator Arrows	
	Point of interest
	Direction of stream flow

Upland Indicators

Name: Av soil horizon. Close-up of 3 inch sample

Description: Vesicular, pale colored, silty soil.

Process: Eolian silt and $CaCO_3$ dust. Carbonate releases CO_2 gas upon wetting which forms bubbles in silt. Accumulates over thousands of years.

Occurrence: Fluvially inactive fan surfaces.

Location: Lucerne Valley, San Bernardino Co

Name: Biotic soil crust.

Description: Soft, puffy, or lumpy dark-colored masses between **clasts**.

Process: Growth of algae and fungus, or mosses on fluvially undisturbed surface.

Occurrence: Uplands, terraces.

Location: Lucerne Valley, San Bernardino Co.

Name: Bioturbation – burrow.

Description: Holes excavated in banks and surfaces.

Process: Animals dig dens and burrows, or excavate same in pursuit of prey, and in the process expose underlying sediment on the “apron” of the burrow.

Occurrence: Common in undisturbed surfaces especially in soft substrate.

Location: El Paso fan, El Paso Mts., Kern Co.

Upland Indicators

Name: Caliche – coating on clast underside (Stage 1+).

Description: Vesicular calcium carbonate coating on underside of cobbles and pebbles.

Process: Evaporation of carbonate-rich groundwater or dissolution and precipitation of eolian carbonate dust. Occurs over thousands of years.

Occurrence: Fluvially inactive fan surface.

Location: El Paso fan, El Paso Mts., Kern Co.

Name: Caliche – layer, Stage IV. Also called petrocalcic horizon; “k” or “ca” soil horizon.

Description: Dense layer of calcium carbonate fills soil voids and coats all clasts.

Process: Evaporation of carbonate-rich groundwater or dissolution and precipitation of eolian carbonate dust. Occurs over thousands of years.

Occurrence: Fluvially inactive, Pleistocene-age fan surface.

Location: El Paso fan, El Paso Mountains, Kern Co.

Name: Caliche – rubble.

Description: Fragments of caliche on surface.

Process: Caliche forms underground; erosion of shallow soil horizons brings it to surface as lag. Deposit exposed by weathering and erosion

Occurrence: Fluvially inactive, Pleistocene-age fan surface.

Location: Pahrump Valley, Inyo Co

Upland Indicators

Name: Carbonate etching

Description: Rilled appearance on surface of limestone clasts.

Process: Acidic rainwater “corrodes” limestone. In-situ chemical weathering.

Occurrence: Fluvially inactive fan surfaces.

Location: Sheep Creek fan, Avawatz Mts., Death Valley, San Bernardino Co

Name: Coppice dunes – relict.

Description: Small bodies of wind-blown sand around and beneath woody vegetation.

Process: As supply of sand decreases, wind removes dune, leaving vegetation and “scar” of original dune.

Occurrence: coppice dunes w/ burrow in area dominated by disrupted out-of-channel flow.

Location: Lucerne Valley, San Bernardino Co

Name: Coppice dunes – active.

Description: Accumulation of wind-blown sand around and beneath vegetation.

Process: Woody vegetation traps eolian sand.

Occurrence: Lower fan, playa fringe.

Location: Pipeline Wash, Death Valley, San Bernardino Co.

Upland Indicators

Name: Deflated surface.

Description: Scattered angular pebbles and cobbles on sandy surface.

Process: Originally deposited as gravel layer, wind removes fine material leaving stony surface.

Occurrence: Fluvially inactive, lower fan surfaces.

Location: Silurian Hills, San Bernardino Co.

Name: Drainage swale.

Description: Shallow, linear depression on fan surface connecting to stream network. Often have more vegetation along margins. Intrinsic part of stream system.

Process: Runoff across fan collects in swale, initiating stream flow.

Occurrence: Transitional feature between upland and watercourse.

Location: Palo Verde Mesa, Riverside Co.

Name: First-order stream.

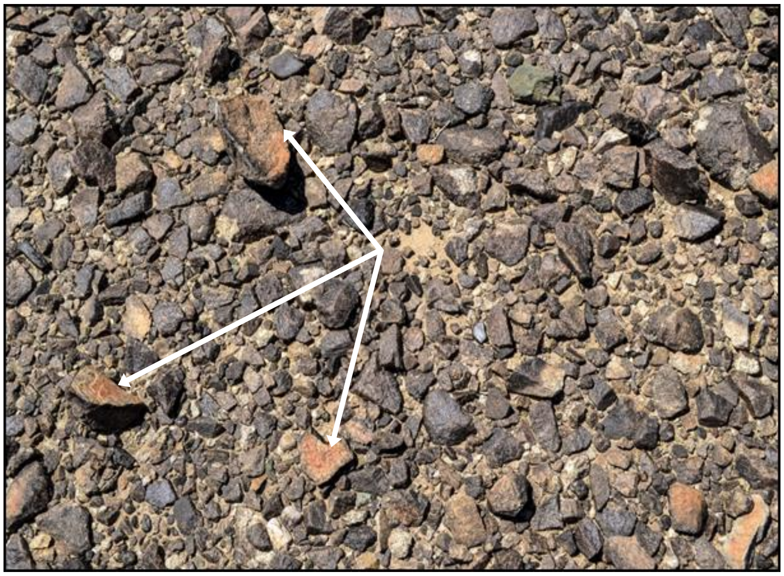
Description: Small stream channel, often with subtle form, inset into fan surface. Drains into higher-order stream.

Process: Runoff across fan surface coalesces in drainage swales which develop into first-order channels.

Occurrence: Transitional feature between upland and watercourse.

Location: El Paso fan, El Paso Mts., Kern Co.

Upland Indicators



Name: Over-turned rocks.

Description: Cobbles having rubified sides up and varnished sides down. Juxtaposition of reddened and darkened clasts (arrows).

Process: Surface runoff deep enough to turns clasts over.

Occurrence: Higher runoff areas of upper to lower fan.

Location: Palo Verde Mesa, Riverside Co.

Name: Pavement – desert pavement.

Description: Surface of tightly interlocking pebbles on fan surface.

Process: Initial gravel deposit and weathering of rocks in place produces pebbles. Wind removes fines leaving "pavement".

Occurrence: Fluvially inactive fan surfaces.

Location: Avawatz Mts., Death Valley, San Bernardino Co.

Name: Relict bar-and-swale.

Description: Linear ridges of cobbles and boulders (bar indicated by arrows), bounding swales infilled by finer gravel usually having desert pavement.

Process: Channel abandonment followed by in-place weathering and in-filling of swale by debris washed in from adjacent bars.

Occurrence: Inactive alluvial fan; areas of low permeability and enhanced runoff can be headwater source areas for first-order streams.

Location: Sheep Creek fan, Avawatz Mts., Death Valley, San Bernardino Co.

Upland Indicators

Name: Rock fractured in place.

Description: Fractured rock surrounded by smaller pieces of same type. Granite and marble are especially susceptible.

Process: In-place chemical weathering.

Occurrence: Upper to lower fan on fluvially inactive surfaces.

Location: Avawatz Mts., Death Valley, San Bernardino Co

Name: Rock varnish.

Description: Dark “stain’ on surface cobbles and pebbles.

Process: Geochemical accumulation of iron, manganese, and clay. Very slow process over thousands of years.

Occurrence: Fluvially inactive alluvial fan surfaces.

Location: Sheep Creek fan, Avawatz Mts., Death Valley, San Bernardino Co.

Name: Rock weathering.

Description: Rock becomes loose and fragmented.

Process: Chemical weathering dissolves unstable mineral grains, fractures rock, and causes reddish stain. Pebbles at arrow were originally a clast of granite.

Occurrence: Fluvially inactive alluvial fan surfaces.

Location: Avawatz Mts., Death Valley, San Bernardino Co.

Upland Indicators

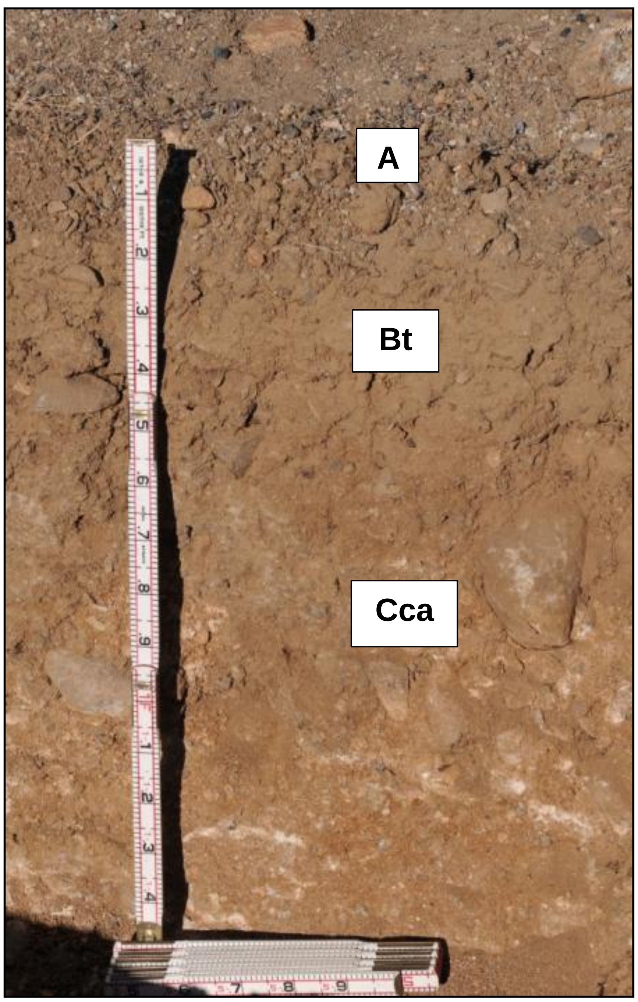
Name: Rubified (reddened) rock. Note Av soil beneath clast.

Description: Top of clast is dark brown varnish; underside is red.

Process: Varnish and rubification = accumulation of iron/manganese oxides and clay + Av (see below) indicating thousands of years of fluvial inactivity.

Occurrence: Fluvially inactive, Pleistocene-age fan surfaces.

Location: Avawatz Mts., Death Valley, San Bernardino Co.



Name: Soil development – in gravel.

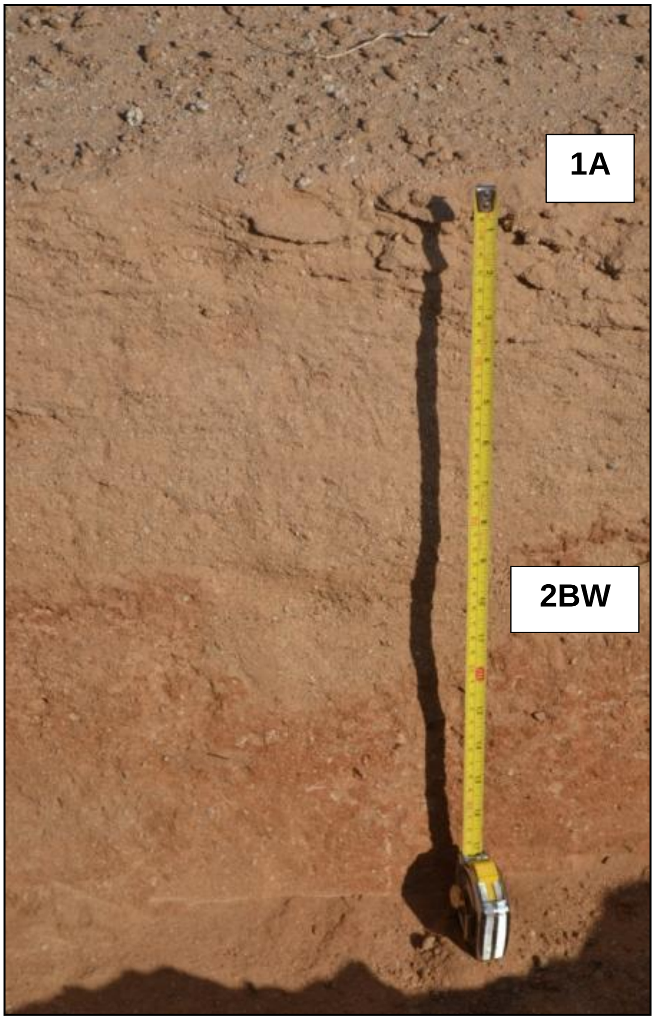
Description: Layering by texture and color of upper layers of substrate. Here, Bt shows as clay accumulation and Cca by patchy carbonate (caliche).

Process: Physio-chemical formation of soil horizons by in-place weathering and formation of new minerals. Takes place over thousands of years. Soils such as this are Pleistocene in age.

Occurrence: Fluvially inactive fan surface.

Location: El Paso fan, El Paso Mts., Kern Co.

Upland Indicators



Name: Soil development – in sand.

Description: Layering by texture and color of upper layers of substrate. Two soils shown here. A lower, red-stained Bw buried by a younger A.

Process: Physio-chemical formation of soil horizons by in-place weathering and formation of new minerals. Takes place over thousands of years. The lower 2Bw horizon is probably Pleistocene in age.

Occurrence: Fluvially inactive fan surface.

Location: Silurian Hills, San Bernardino Co.

Name: Surface rounding of landforms.

Description: Rounded topographic morphology.

Process: Through time, topography becomes rounded. Topography in fluvially active environments tends to be sharper and more angular.

Occurrence: Fluvially inactive alluvial fan surfaces.

Location: Palo Verde Mesa, Riverside Co.

Upland Indicators

Name: Woody debris in place.

Description: Woody debris beneath and adjacent to source.

Process: When no flows disturb it, woody debris accumulates beneath and adjacent to the plants that produced it.

Occurrence: Fluvially inactive fan surfaces, terraces and islands.

Location: Palo Verde Mesa, Riverside Co.

Watercourse Indicators: Fluvial Transport, Deposition and Out-of-Channel Flow

Name: Bar – mid-channel gravel.

Description: Lens-shaped accumulations of gravel often fining in grain size downstream.

Process: Waves of bedload move downstream during high flows and their shapes are modified by varying water energy levels.

Occurrence: Channel.

Location: Amargosa River, Death Valley, San Bernardino Co.

Name: Bar – mid-channel gravel, degraded.

Description: Mid-channel accumulation of gravel, but typical lens shape is degraded and dissected by numerous small channels.

Process: Increase in erosional capability of channel due to more water or less sediment load.

Occurrence: Channel.

Location: Lucerne Valley, San Bernardino Co.

Name: Bars – small gravel in swale (arrow).

Description: Patch of loose gravel on top of flattened vegetation in depression of swale.

Process: Small gravel bar on swale indicating recent stream flow.

Occurrence: Swale, floodplain.

Location: El Paso fan, El Paso Mts., Kern Co.

Watercourse Indicators: Fluvial Transport, Deposition and Out-of-Channel Flow

Name: Bars – sand (view upstream).

Description: Sand in lens-shaped bodies tapering and fining downstream.

Process: Bedload sand transported in waves on channel bottom. Sand transported to next bar downstream. As flow velocity decreases, sand deposited.

Occurrence: Channel and floodplain.

Location: Coxcomb fan, Coxcomb Mts., Riverside Co.

Name: Bar – sand (detail).

Description: Low-angle cross bedding in dissected point or longitudinal bar of pebbly, fine to coarse-grained sand; indicative of stream deposit.

Process: Records the downstream migration of the bar as sand moving on the stream bed is deposited on downstream end of the bar. Bar migrates downstream.

Occurrence: Channel edges.

Location: Palo Verde Mesa, Riverside Co.

Name: Bifurcated flow (view upstream).

Description: Multiple channels.

Process: Flow in channel divides around obstructions such as bed deposits or vegetation. Usually in low-gradient streams.

Occurrence: Channel and floodplain.

Location: Sheep Creek fan, Avawatz Mts., Death Valley, San Bernardino Co.

Watercourse Indicators: Fluvial Transport, Deposition and Out-of-Channel Flow

Name: Bifurcated flow (view downstream)

Description: Multiple channels.

Process: Flow in channel divides around obstructions such as bed deposits or vegetation. Usually in low-gradient streams.

Occurrence: Channel and floodplain.

Location: Pipeline Wash, Avawatz Mts., Death Valley, San Bernardino Co.

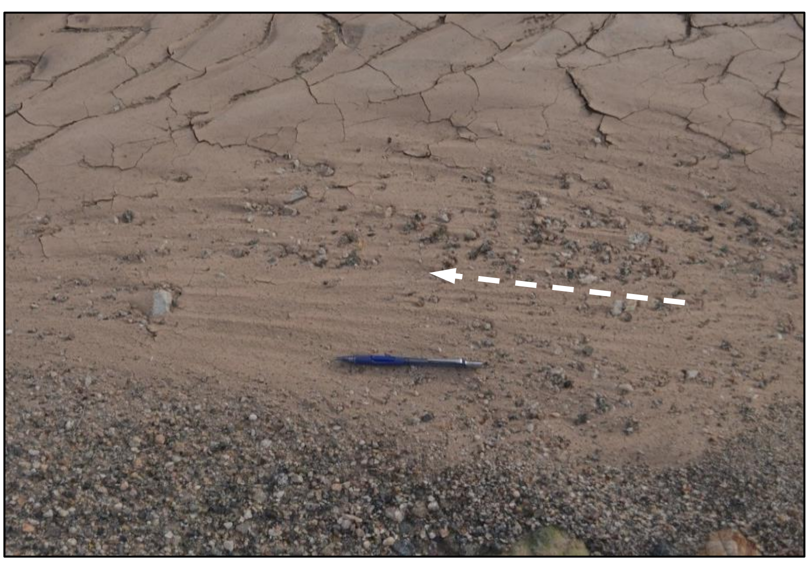
Name: Drainage swales (view upstream).

Description: Shallow, linear depression on fan surface connecting to stream network. Intrinsic part of stream system. Note robust creosote bush in swale compared to barren fan surface.

Process: Runoff across fan collects in swale, initiating stream flow.

Occurrence: Mid and lower fan.

Location: Silurian Hills fan, San Bernardino Co.



Name: Flow lineations.

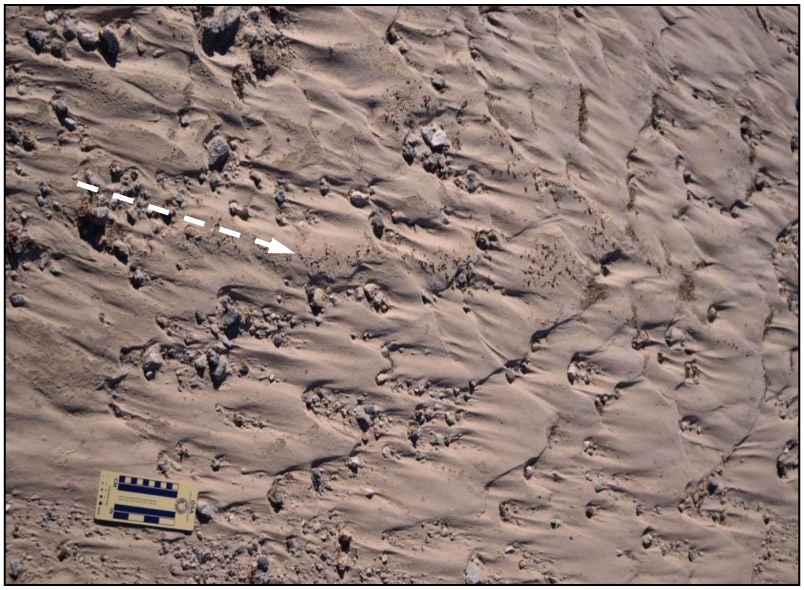
Description: “Tear-drop” shaped bodies of fine sediment tapering downstream from pebbles.

Process: Sub-laminar flow velocities deposit fine sediment parallel to flow direction in wake of obstruction.

Occurrence: Channel and floodplain.

Location: Salt Creek, Avawatz, Mts., San Bernardino Co.

Watercourse Indicators: Fluvial Transport, Deposition and Out-of-Channel Flow



Name: Flow lineations with scour, and sinuous ripple marks.

Description: Lineations formed of small scours and sediment tails extending downstream incised into ripples.

Process: Initial sediment-laden flow followed by relatively clear water scour.

Occurrence: Channel and floodplain.

Location: Sheep Creek fan, Avawatz Mts., Death Valley, San Bernardino Co.

Name: Imbricated gravel (side view).

Description: Overlapping and semi-flattened clasts oriented in the direction of flow.

Process: Water turns bedload clasts in flow direction.

Occurrence: Channel.

Location: Titus Canyon Formation, eastern Death Valley, San Bernardino Co.

Name: Levee ridges.

Description: Sub-parallel alignments of coarse detritus separated by swales of finer sediment. Note first-order channel in left background.

Process: Debris flow margins and tops of high-flow channel edges.

Occurrence: Channels and floodplains.

Location: Coxcomb Mts., Riverside Co.

Watercourse Indicators: Fluvial Transport, Deposition and Out-of-Channel Flow

Name: Mud cracks.

Description: Cracked clayey sediment.

Process: Evaporation and infiltration of water deposits suspended sediment which desiccates upon drying. Note bird tracks.

Occurrence: Floodplain, playa.

Location: Salt Spring Hills fan, San Bernardino Co.

Name: Mud curls.

Description: Sheets of fine silt and sand.

Process: Suspended sediment (mainly clay) deposited on bottom by infiltration and evaporation of water. Desiccation dries and curls mud. Note ripple marks in right foreground.

Occurrence: Channel, floodplain, playa.

Location: Pipeline Wash, Avawatz Mts., Death Valley, San Bernardino Co.

Name: Mud drape.

Description: Close-up of mud drape (clay) layer covering clasts.

Process: Evaporation and infiltration of standing water deposits suspended load of clay.

Occurrence: Channel, floodplain, playa.

Location: Salt Creek, Avawatz Mts., Death Valley, San Bernardino Co.

Watercourse Indicators: Fluvial Transport, Deposition and Out-of-Channel Flow

Name: Organic drift.

Description: Clotted organic matter (creosote chaff) on channel margin.

Process: Organic flotsam deposited by out-of-channel flow as water evaporates and infiltrates. Note flow lineations in channel.

Occurrence: Channel, floodplain, playa.

Location: Sheep Creek fan, Avawatz Mts., Death Valley, San Bernardino Co.

Name: Organic drift (on mud drape).

Description: Clotted organic matter (creosote chaff) with layer of mud. Note flow lineations to right.

Process: Organic flotsam concentrated and deposited as water evaporates and infiltrates.

Occurrence: Channel, floodplain, playa.

Location: Coxcomb fan, Coxcomb Mts., Riverside Co.

Name: Out-of-channel flow.

Description: Finer-grained floodplain sediment in contrast to coarser-grained sediment of the upland and active channel.

Process: Capacity of the stream channel is exceeded and out-of-channel flow moves across the floodplain areas depositing fine sediment.

Occurrence: Floodplains.

Location: Lucerne Valley, San Bernardino Co.

Watercourse Indicators: Fluvial Transport, Deposition and Out-of-Channel Flow

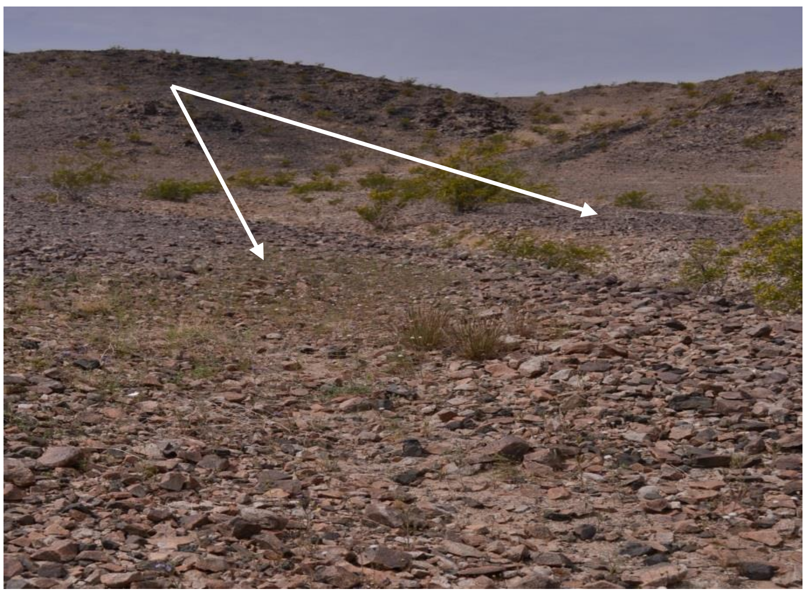
Name: Out-of-channel flow (view upstream).

Description: Broad area of flow indicators on nearly flat surface.

Process: Defined channel form ended at the playa margin (white arrow) and unconfined flow spread laterally across the terminal floodplain of the stream toward the playa fringe.

Occurrence: Channel, floodplains, stream-playa margin.

Location: Silurian Hills fan, San Bernardino Co.



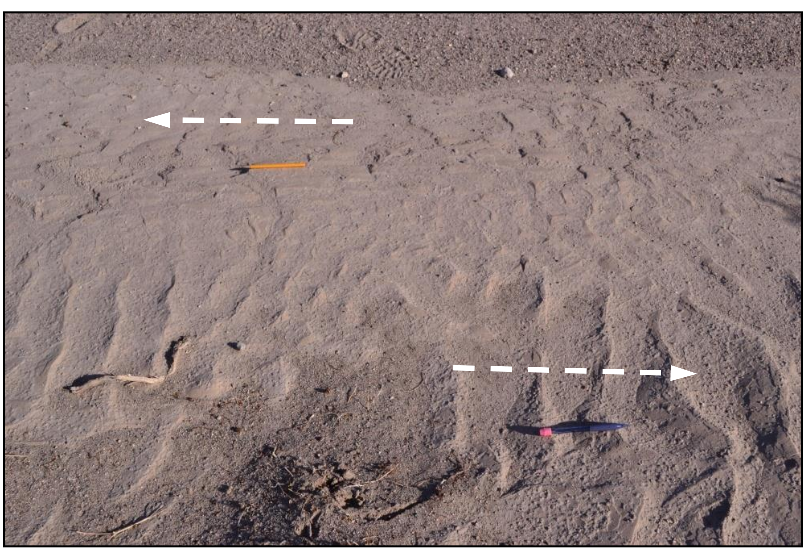
Name: Overturned rocks.

Description: Overturned rocks with lighter, unweathered, unvarnished, non-rubified undersides exposed in a drainage swale/first-order stream. Note contrast with fluvially undisturbed varnished rock surface upland (arrows).

Process: Runoff turns clasts over. Formerly stable surface experiences turbulent flow of water.

Occurrence: Active swales and low-order streams.

Location: Palo Verde Mesa, Riverside Co.



Name: Ripples – eddy.

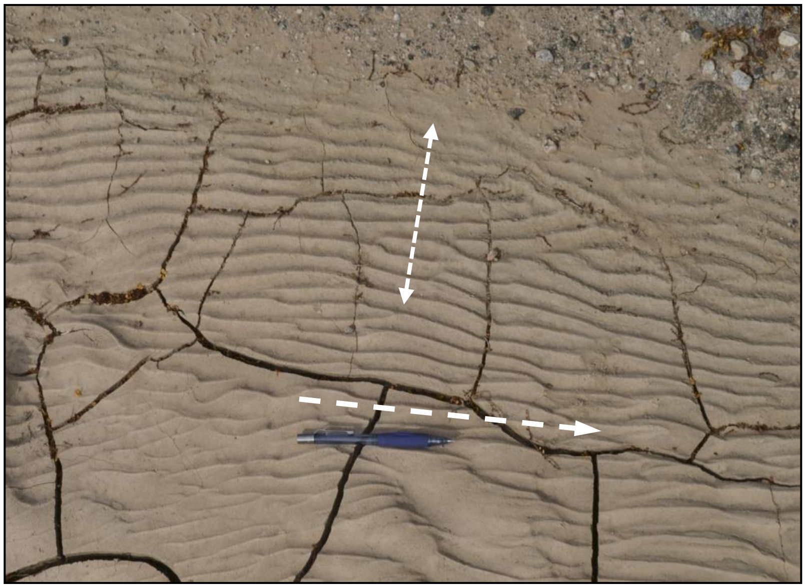
Description: Asymmetrical, arcuate ripple marks having opposing steep faces.

Process: Eddy in flow due to embayment in channel margin.

Occurrence: Channel and floodplain.

Location: Salt Creek, Avawatz Mts., Death Valley, San Bernardino Co.

Watercourse Indicators: Fluvial Transport, Deposition and Out-of-Channel Flow



Name: Ripples – oscillation.

Description: Sub-parallel, symmetrical ridges in fine-grained sediment. Note intersecting ripple crests.

Process: Wind-generated standing waves oscillating in standing water (dashed arrow). Ripple crests parallel channel margin are unrelated to flow (solid arrow).

Occurrence: Channel and floodplain.

Location: Silurian Hills fan, San Bernardino Co.

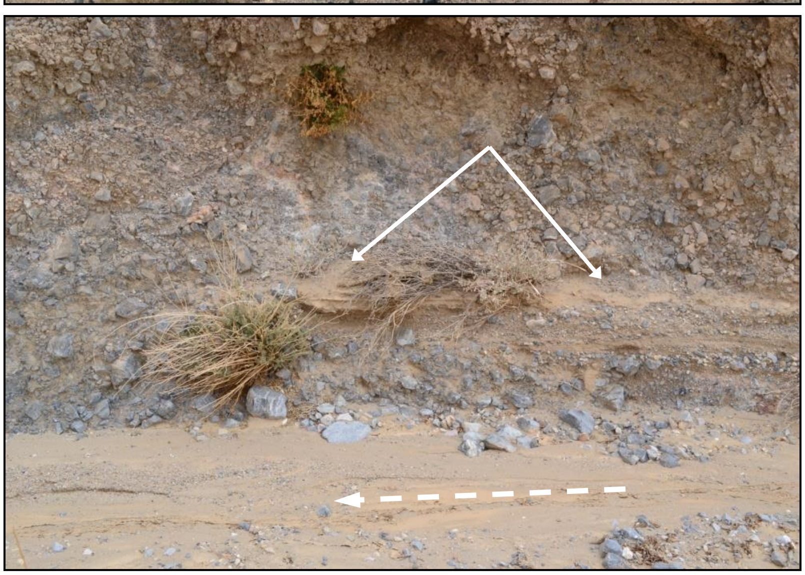
Name: Secondary channel (view upstream).

Description: Active channel incised into floodplain.

Process: High flows “jump” out of main channel and spread laterally, scouring new channel into floodplain.

Occurrence: Floodplain.

Location: Salt Creek, Avawatz Mts., Death Valley.



Name: Sediment plastering – sand.

Description: Bedded sand stuck on channel wall (dashed arrows).

Process: Channel carved by incision. Subsequent flow event partly fills channel with sediment which erodes in later flow, leaving small patch of sand behind. Note vegetation bent downstream in the direction of stream flow.

Occurrence: Channel.

Location: Lucerne fan, San Bernardino Co.

Watercourse Indicators: Fluvial Transport, Deposition and Out-of-Channel Flow

Name: Sediment plastering – gravel.

Description: Gravel stuck to channel wall (not interbedded).

Process: Channel carved by incision. Subsequent flow event partly fills channel with gravel which erodes in later flow, leaving patch of gravel behind.

Occurrence: Channel.

Location: Lucerne Valley, San Bernardino Co.

Name: Sediment ramp – gravel (view downstream).

Description: Gravel accumulation on upstream side of obstruction (burro brush).

Process: Bedload gravel cannot pass obstruction even during high flow.

Occurrence: Channel.

Location: El Paso Wash, El Paso Mts., Kern Co.

Name: Sediment ramp – sand (view upstream).

Description: Sand accumulation on upstream side of obstruction (wrack).

Process: Bedload sand obstructed during high flow.

Occurrence: Channel.

Location: Lucerne Valley, San Bernardino Co.

Watercourse Indicators: Fluvial Transport, Deposition and Out-of-Channel Flow

Name: Sediment sheet – gravel.

Description: Thin, planar beds of sediment at channel end.

Process: Sub-parallel channels lose form so sediment-laden flow spreads laterally.

Occurrence: Playa fringe.

Location: Silurian Hills fan, San Bernardino Co.

Name: Sediment sorting (view downstream).

Description: Lateral distribution of sediment size from coarsest in channel bottom to finer along margin.

Process: Deeper water flows faster so can carry larger particles.

Occurrence: Channel.

Location: Salt Creek, Avawatz Mts., Death Valley, San Bernardino Co.

Name: Sediment tail – in sandy gravel (view downstream).

Description: Sand accumulation on downstream side of boulders.

Process: Bedload sand deposited in low-velocity zone downstream of obstruction during high flow.

Occurrence: Channel.

Location: Salt Creek, Avawatz Mts., Death Valley, San Bernardino Co.

Watercourse Indicators: Fluvial Transport, Deposition and Out-of-Channel Flow

Name: Sediment tail – sand (view downstream).

Description: Sand accumulation on downstream side of vegetation.

Process: Bedload sand deposited in low-velocity zone downstream of obstruction during high flow.

Occurrence: Channel.

Location: Salt Creek, Death Valley, San Bernardino Co.

Name: Vegetation-channel alignment.

Description: Vegetation larger, more abundant, or more robust along channel margins.

Process: High water infiltration rates in well-drained sandy/gravelly soils typical of recent stream deposits allow water to infiltrate to deep moisture zones protected from evaporation where it is available to vegetation

Occurrence: Channel margins.

Location: Sheep Creek fan, Avawatz Mts., Death Valley, San Bernardino Co.

Name: Vegetation-channel alignment, on swale.

Description: Vegetation larger, more abundant, or more robust along in and along swales.

Process: Greater availability of water promotes vegetation growth.

Occurrence: Swales, first-order channels.

Location: Palo Verde Mesa, Riverside Co.

Watercourse Indicators: Fluvial Transport, Deposition and Out-of-Channel Flow

Name: Wrack, large, on floodplain (view downstream).

Description: Accumulation of organic debris on upstream side of obstructions on floodplain.

Process: High flows tear out plants and woody debris which get stuck on rocks, vegetation, or other objects.

Occurrence: Channel, floodplain.

Location: Lower Salt Creek, Avawatz Mts., Death Valley, San Bernardino Co.

Name: Wrack, small, on floodplain.

Description: Arcuate accumulation of twigs and organic matter on upstream side of obstruction on floodplain.

Process: **O**ut-of-channel flow carries organic matter across floodplain.

Occurrence: Floodplain, channel.

Location: Palo Verde Mesa, Riverside Co.

Name: Wrinkle marks.

Description: Small, discontinuous, more or less parallel ridges and hollows. Orderliness of the pattern varies from poor to good; resemble small, linear ripple marks.

Process: Sheet flow or rainfall impact on loose over-bank deposits of fine sand.

Occurrence: Loose, fine grained sand deposits on high point bars and floodplains

Location: Lucerne Valley, San Bernardino Co.

Watercourse Indicators: Fluvial Erosion

Name: Cut bank – in sand.

Description: Vertical, unstable stream bank.

Process: Stream channel widens or changes course, eroding banks.

Occurrence: Active channel margin.

Location: Coxcomb fan, Coxcomb Mts., Riverside Co.

Name: Cut bank – gravel, with exposed roots.

Description: Vertical, unstable stream bank.

Process: Stream channel widens or changes course, eroding banks. Roots exposed.

Occurrence: Channel.

Location: Salt Creek, Avawatz Mts., Death Valley.

Name: Exposed roots.

Description: Roots of woody vegetation exposed in channel wall and bottom.

Process: Stream channel widens and deepens, eroding banks and bed, exposing roots.

Occurrence: Channel.

Location: Unnamed wash, Pinto Mountains, Riverside Co.

Watercourse Indicators: Fluvial Erosion

Name: Headcut – initial stage.

Description: Small step in channel bottom.

Process: Downcutting as flow increases or sediment load decreases. Headcut will migrate upstream.

Occurrence: Channel.

Location: Pipeline Wash, Avawatz Mts., Death Valley, San Bernardino Co.

Name: Headcut in first-order channel on terrace.

Description: Step in channel gradient in wind-blown sand on upland surface.

Process: Despite high infiltration of sand, intense rainfall causes flow in small, first-order channel which easily erodes soft sediment.

Occurrence: Lower fan; playa fringe.

Location: Palo Verde Mesa, Riverside Co.

Name: Headcut – large.

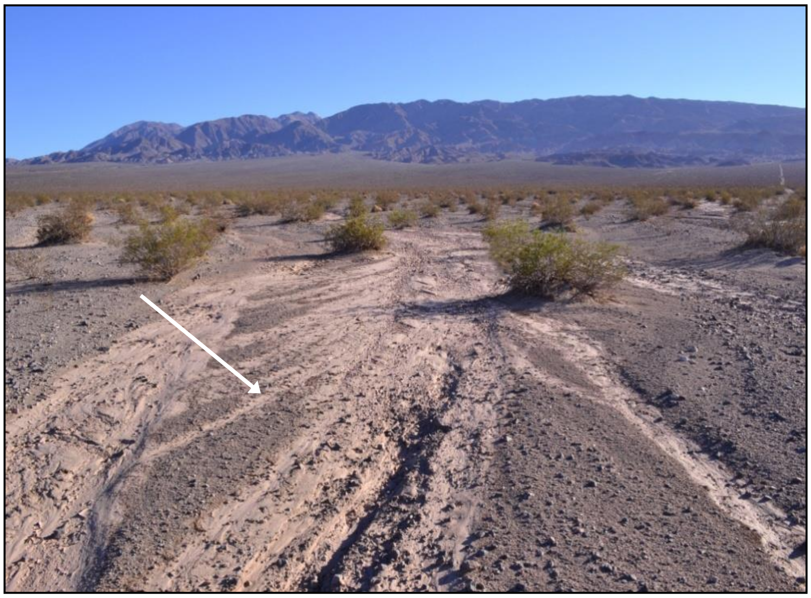
Description: Channels cut into bank at confluence of two streams.

Process: Gradient difference between two streams causes steeper one to downcut.

Occurrence: Channel.

Location: Pipeline Wash, Avawatz Mts., at confluence with Amargosa River, Death Valley, San Bernardino Co.

Watercourse Indicators: Fluvial Erosion



Name: Rills – cross-bar (view upstream).

Description: Grooves cutting diagonally across sand or gravel bar.

Process: Water drains from secondary channel (R) into main channel (L) during waning stage, scouring bar in between.

Occurrence: Channel.

Location: Pipeline Wash, Avawatz Mts., Death Valley.

Name: Scour – stream bank.

Description: Trough at side of channel deeper than surrounding channel bottom.

Process: Turbulence created by obstruction (here, exposed roots at arrow) erodes channel bottom immediately downstream. Sediment usually deposited as "tail".

Occurrence: Entire watercourse but most common in mid fan channels.

Location: Coxcomb fan, Coxcomb Mts., Riverside Co.

Name: Scour - channel bottom (view downstream).

Description: Trough in channel deeper than surrounding bottom.

Process: Turbulence created by obstruction erodes sediment in channel. Process by which channel deepens.

Occurrence: Entire watercourse but most common in mid fan channels.

Location: Salt Creek, Avawatz Mts., Death Valley, San Bernardino Co.

Watercourse Indicators: Fluvial Erosion

Name: Secondary channel (view upstream).

Description: Active channel incised into floodplain.

Process: High flows “jump” out of main channel and spread laterally, scouring new channel into floodplain.

Occurrence: Floodplain.

Location: Salt Creek, Avawatz Mts., Death Valley, San Bernardino Co.

Name: Water-cut benches.

Description: Stair-step configuration along channel margin.

Process: Fluctuating water levels and energy, and differential erodibility.

Occurrence: Channel.

Location: Lucerne Valley, San Bernardino Co.

Name: Water-cut benches.

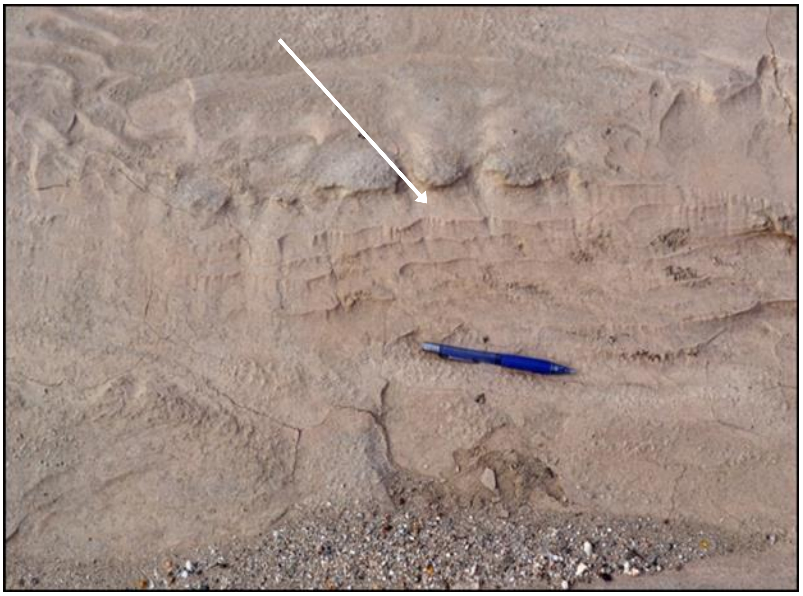
Description: Stair-step configuration along channel margin.

Process: Fluctuating water levels and energy, and differential erodibility.

Occurrence: Channel.

Location: Lucerne Valley, San Bernardino Co.

Watercourse Indicators: Fluvial Erosion



Name: Water level marks.

Description: Sub-parallel lines on sides of basins or banks.

Process: Agitation of water during falling stage erodes fine-grained sediment. Note rills on top due to return flow across floodplain.

Occurrence: Lower fan, river, playa fringe.

Location: Salt Creek, Avawatz Mts., Death Valley, San Bernardino Co.

Watercourse-Playa Fringe Indicators

Name: Algal crusts – weathered. Darker area in center of photo is a spring.

Description: Thin algal coating on mud cracks.

Process: Algae desiccates upon drying. Susceptible to weathering upon exposure.

Occurrence: Playa.

Location: Silurian Hills fan, San Bernardino Co.

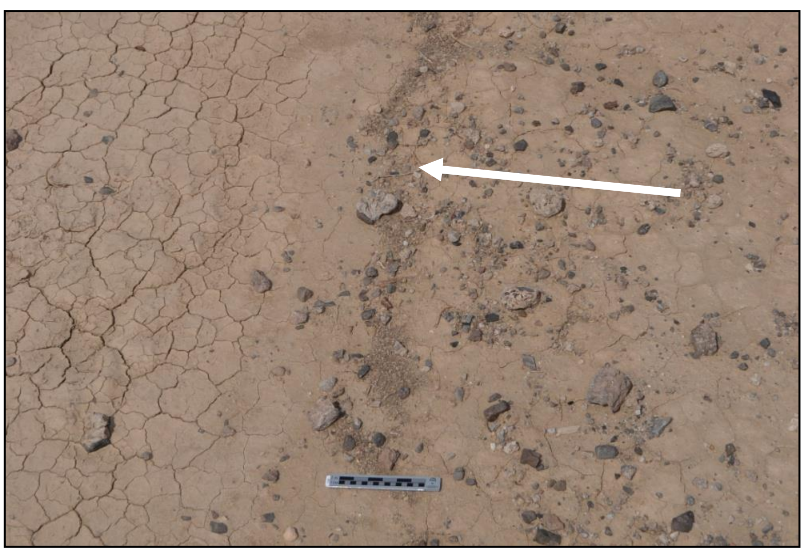
Name: Relict beach ridge -- large.

Description: Stepped edge along shoreline.

Process: Wind-driven waves erode shoreline as water level drops.

Occurrence: Relict lakes, Playas.

Location: Lake Tecopa, San Bernardino Co.



Name: Beach ridge – small.

Description: Linear deposits of gravel and sand along lake margin.

Process: Stream entering lake loses energy to transport bedload, abruptly deposits at shoreline. Note mud cracks beneath ridge from earlier higher stand of lake.

Occurrence: Fan-playa fringe.

Location: Silurian Lake, San Bernardino Co.

Watercourse-Playa Indicators

Name: Biotic soil crusts

Description: soil aggregates held together by algae, fungi, lichens or mosses and the substances they produce.

Process: Growth of algae, fungi, lichens or mosses and their bi-products on alluvial slopes above playa.

Occurrence: Beach ridge beyond the present each of waves and ponding.

Location: Lake Tecopa, San Bernardino Co.

Name: Coppice dunes – active.

Description: Equigranular, fine-grained sand around woody vegetation.

Process: Wind-blown sand accumulates around woody vegetation which continues to grow through it.

Occurrence: Fan-playa fringe, floodplain, fluvially inactive uplands.

Location: Amargosa River, Avawatz Mts., Death Valley, San Bernardino Co.

Name: Coppice dunes – relict.

Description: Oval "scars" around (usually dead) woody vegetation and minor sand. Note mud curls in foreground.

Process: Older coppice dunes blew away as sand supply decreased and was insufficient to replace sand removed.

Occurrence: Playa, floodplain.

Location: Silurian Lake, San Bernardino Co.

Watercourse-Playa Indicators

Name: Relict crust – carbonate; tufa

Description: Surface veneer of porous limestone.

Process: Precipitation of limestone around a variety of organic structures, such as reeds, plant roots, leaves; often associated with lake springs.

Occurrence: Playa.

Location: Pahrump Valley, Inyo Co.

Name: Crust – salt/soda.

Description: Soluble efflorescence coating surface.

Process: Salts and soda minerals precipitate as water evaporates.

Occurrence: Playa.

Location: Silurian Lake, San Bernardino Co.

Name: Mud cracks – Polygonal mud cracks

Description: Polygonal cracks in fine-grained rippled shoreline or stream edge sediment.

Process: Shrinkage as clay desiccates.

Occurrence: Playa.

Location: Silurian Lake, San Bernardino Co.

See also mud curls and drapes in Watercourse - Fluvial Processes.

Watercourse-Playa Indicators

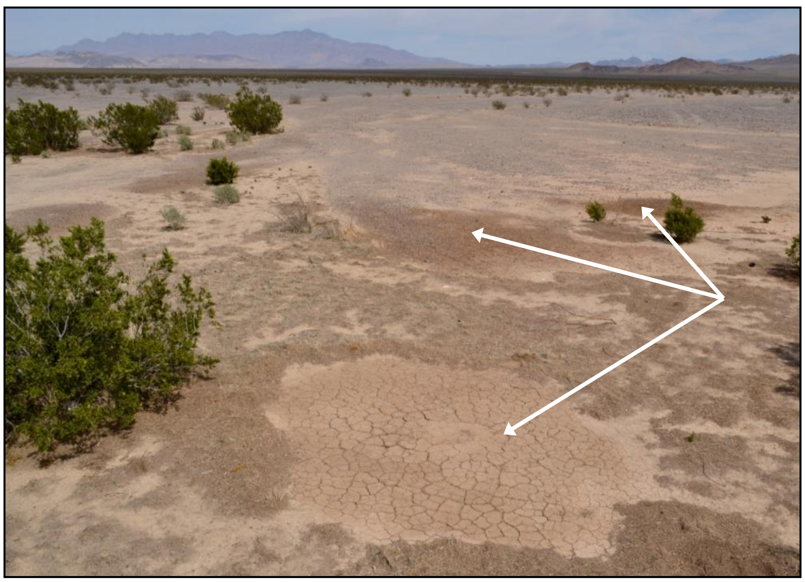
Name: Sand-filled channel (view upstream).

Description: Linear depression filled with fine, equigranular sand.

Process: Eolian sand fills channel where it is protected from further wind erosion, but often washes out when stream flows.

Occurrence: Floodplain, playa margin.

Location: Sheep Creek fan, Avawatz Mts., Death Valley, San Bernardino Co.



Name: Springs.

Description: Semi-circular areas of wet or recently wet sediment in otherwise dry environs. 3 springs shown (at arrows).

Process: Groundwater from fan rises to surface at playa margin. Feeds vegetation.

Occurrence: Playa fringe.

Location: Silurian Hills fan/Silurian Lake, San Bernardino Co.

Name: Substrate staining.

Description: Discoloration of fine-grain sediment. Reddish, brown, black, white are most common.

Process: Organic material (mainly algae) or precipitation of minerals stains soil.

Occurrence: Playa fringe or floodplain.

Location: Silurian Lake, San Bernardino Co.

Watercourse-Playa Indicators

Name: Vegetation alignments.

Description: Rows of verdant plants in otherwise sparsely vegetated landscape.

Process: Ground and surface water follows channels even when poorly defined.

Occurrence: Playa fringe.

Location: Silurian Hills fan, San Bernardino Co.

Glossary

The terms below paraphrase a variety of sources relevant to stream ecology, geomorphology and hydrology modified so as to be relevant to arid landscapes (Alluvial Fan Task Force 2010a, 2010b; Bates and Jackson 1984; Blair and McPherson 1994; CDFW 2010; Elzinga et al.1998; North and Davidson 2011; Picard and High 1973; Sawyer et al 2009; Wilson and Moore 1998).

A Soil Horizon	Uppermost mineral soil horizon characterized by paler color than parent material, and obliteration of its structure. Zone of downward leaching of mineral matter but may be enriched with eolian dust to form Av horizon (see below). Unlike in humid areas, arid A horizons have little organic matter.
Abandoned channel	Stream channels that no longer convey water and sediment from the upland drainage basin. See *Relict*.
Active channel	A channel receiving frequent enough flow to leave physical or biological evidence of fluvial activity on the landscape.
Absolute cover	A measure of the percent of ground covered by the crowns of all live perennial and shrub species within a sample area as viewed from above. Compare to *relative cover.*
Abundance	The relative amount of a species in a particular ecosystem. Measures of plant abundance are approximated by counting the number of individuals in a sample area. Qualitative descriptors of relative abundance of a species might include terms such as "rare," "occasional," "common," and "abundant". A given species might occur in both uplands and fluvially active units, but may be abundant in one and rare or occasional in the other.
Algal crusts	Biotic crusts composed of water-stable soil aggregates held together predominantly by algae but also fungi, lichens or mosses and the substances they produce; algal crusts occur predominantly in areas prone to water ponding. See *Biotic soil crusts.*
Alluvial fan	Gently sloping fan-shaped landforms that form where steep, confined mountain streams flow out onto a mountain front. They often resemble extended fans when viewed on maps or aerial photographs, but their morphology can be irregular forms bounded laterally by adjacent fans, bedrock outcrops, and relict fan surfaces.
Alluvial fan apex	The point at which an alluvial fan is last confined within the mountain front
Alluvial fan apron	The continuous, blanket-like deposit of alluvium formed by coalescing alluvial fans at the base of mountain ranges
Alluvial plain	A plain formed by the deposition of water-transported sediment.
Alluvium	Unconsolidated clay, silt, sand, and gravel deposited as sorted or semi-sorted sediment in the bed of a stream or its floodplain or delta, or as a fan at the base of a mountain slope.

Anthropogenic disturbance or influence	Disturbances or influences caused by or attributed to humans.
Av Horizon	Soil horizon characterized by the dominance of vesicular pores, typically of lighter color than the underlying soil horizons. Vesicular pores are formed in the silt- to fine sand-rich eolian material through cyclic-wetting and drying. Air bubbles trapped during wetting expand as the surface is heated during drying leaving imprints as discontinuous, spherical vesicular pores. Av horizons indicate soils thousands of years in age and so indicate stabilized surfaces no longer subject to fluvial processes.
Avulsion	A sudden cutting off or separation of land by a flood or by an abrupt change in the course of a stream, as by a stream breaking through a meander or by a sudden change in flow direction whereby the stream deserts its current channel to join or form another.
Axial valley stream	A stream of an intermontane valley, flowing in the deepest part of the valley and parallel to its longest dimension.
Bajada	A broad, continuous alluvial slope or gently inclined depositional surface extending from the base of mountain ranges out into and around an inland basin, formed by the lateral coalescence of a series of separate but confluent alluvial fans.
Bank	The land that confines or otherwise defines the outermost boundary of a lake or stream, when its waters rise to the highest level of confinement.
Bankfull flow	The flow that fills the active channel to a stage above which any further increase flows across the floodplain and spreads to topographically higher secondary channels and (or) floodplains.
Bar and Bar types	A general term for a ridge-like accumulation of sand, gravel, or other alluvial material formed in the channel, along the banks, or at the mouth of a stream where a decrease in velocity induces deposition. Examples include**:** point bars formed on the inside of meander channels; mid-channel bars formed within the channel.
Bar and Swale morphology	Shallow stream- or debris-flow channels separated by ridges of gravel and cobble.
Beach ridge	A low, essentially continuous mound of beach or beach and dune material (sand, gravel, organic debris) on the backshore of a beach beyond the present limit of waves.
Bed	The land beneath a lake and its shoreline boundary, or beneath a stream and its outermost banks.
Bedload	The part of the total stream sediment load that is moved on or immediately above the stream bed, such as the larger, heavier boulders, pebbles, gravels; the part of the load that is not continuously in suspension.
Bifurcated flow	The separation or branching of a stream into one or more parts.

Biotic community The animal and plant life of a region.

Biotic soil crusts Biological soil crusts that occur predominantly on dunes, alluvial slopes, and other areas that do not pond water. Water-stable soil aggregates held together by algae, fungi, lichens or mosses and the substances they produce; an intimate association between soil particles and cyanobacteria, algae, microfungi, lichens, and bryophytes (in different proportions) which live within or in the top of the uppermost millimeters of soil. Distinguished from "physical soil crusts," or abiotic crusts such as salt crusts

Bioturbation The reworking of sediment by organisms, such as small mammal burrows and the burrow "apron" or tailings.

Bk and Bt Horizons In soil development, the B horizon is the "zone of accumulation". It consists of mineral layers which may contain concentrations of clay or minerals such as iron or aluminum oxides or organic material leached from the overlying A horizon, and which formed in place. It is defined by having a distinctly different structure or consistency to the A horizon above and the horizons below. They usually have stronger colors than the A and C horizons.

Bw Horizon B soil horizon with notable reddening of hue due to in-situ oxidation of iron-bearing minerals; may include development of soil structure.

Boulder A somewhat rounded, detached rock mass larger than a cobble, having a diameter greater than 256 mm.

Elevated sandy deposits between channels.

Braided channel A watercourse with multiple active shallow channels that divide and rejoin to form a pattern of gently curved channel segments separated by exposed ephemeral islands or channel bars.

Caliche Calcium carbonate-rich deposit in soils of arid and semi-arid regions that is formed by the capillary rise of carbonate-bearing water toward the surface where it is deposited by evaporation.

Cca Horizon C soil horizon enriched by secondary carbonate exceeding that of the parent material; shows as coatings, concretions, or soft masses.

Cambic-argillic (B) Horizon Mineral B soil horizon characterized by a texture of clayey very fine sand or finer, a soil structure rather than rock structure, and clay accumulation, usually as coatings on the surface of particles or pores, or as bridges between sand grains.

Carbonate A rock consisting chiefly of carbonate minerals, such as limestone or dolomite; sediment formed by the biotic or abiotic precipitation from aqueous solution of carbonates of calcium, magnesium, or iron.

Carbonate etching Microsolution grooves and pitting on the surface of carbonate rocks.

Channel	A defined course along which water flows perennially or episodically. Channels may be active during every runoff event or spatially or temporally dormant features within a larger watercourse that receive water periodically during higher flows.
Clasts	An individual grain, or fragment of a sediment or rock, produced by the mechanical or chemical disintegration of a larger rock mass.
Clay	A detrital particle finer than silt and smaller than 0.0625 mm.
Cobble	An often rounded rock fragment larger than a pebble and smaller than a boulder, having a diameter in the range of 64-256 mm.
Co-dominant species	Two or more abundant species with high percent cover in relation to other species with the highest percent cover. Co-dominant species are generally defined as those with at least 30% relative cover. See also *dominant species, relative cover, and absolute cover*.
Compound channel	Channels characterized by a single meandering, low-flow channel nested within a larger watercourse defined by a frequently shifting, channel network. The most common channel form for larger streams on dryland regions.
Confined flow	Water flowing in stream channels, and retained between channel banks. The term *channelized flow* is here reserved for various forms of channel engineering, such as straightening and deepening, levee construction, or for flood management.
Coppice dunes	Accumulations of sand at the base of small trees or shrubs.
Deflation	Removal or “blowing out” of fine-grained sediment by the wind.
Density	As used here, a measure of the total number of individual shrubs and perennials (all species combined) within a sample area. In the absence of defined plots and plot counts, simple qualitative descriptors of density may be used to compare two different units (upland units vs. watercourse complex or fluvially active units). These might include “same”, “slightly greater than (or less than)”, and “significantly greater than (or less than)”.
Desert pavement	A closely packed stony surface generally composed of a layer of angular or subrounded gravels one or two stones thick sitting on a layer of finer stone-free, eolian-derived fine sediment.
Discontinuous channel	A channel along which fluvial processes change from degradation to aggradation and a well-defined channel form is periodically lost along the stream length.
Distributary channels, flow, streams, or patterns	Channels flowing away from the main stream and generally not rejoining it. The number of channel forks commonly exceeds the number of channel confluences, creating a divergent distributary, rather than convergent tributary drainage pattern.

Dominant species — An abundant species with a higher percent vegetative cover relative to other species. In this case, only perennial and shrub species are considered because the percent cover and density of annuals is highly variable due to variable and unpredictable rainfall. Dominant species are typically defined as those with at least 50% *relative* cover within the sample area

Dormant channel — A channel isolated from its principal water source by natural causes or human constructs such as roads, but that retains its potential for hydrologic reactivation and attendant stream function

Drainage network or system — All the streams and other water bodies that drain a region and contribute flow to larger stream or lake.

Eco-hydrology — The interplay between ecological and hydrological processes from molecular to river basin scales. An essential component of eco-hydrology is a rigorous understanding of hydrobiology, from ecosystem properties, dynamics and functions to modeling of abiotic and biotic interactions at the basin scale.

Ecohydrological or Ecological integrity — Ecohydrological integrity expresses the degree to which the physical, chemical, and biological components (including composition, structure, and process) of an ecosystem and their relationships to the local hydrology are present, functioning, and capable of self-renewal. Ecological integrity implies the presence of appropriate species, populations and communities and the occurrence of ecological processes at appropriate rates and scales as well as the environmental conditions that support these taxa and processes.

Ecosystem — A spatially explicit unit of the Earth that includes all of the organisms, along with all components of the abiotic environment within its boundaries.

Eolian — Pertaining to the wind; especially such deposits as dune sand, and of sedimentary structures such as wind-formed ripple marks, or of erosion and deposition accomplished by the wind.

Episodic stream — Streams having intermittent or ephemeral flow that are dry or have very low flow over decadal time scales. Large events that convey flow and/or sediment to affect channel morphology occur infrequently (i.e., once or twice per decade).

Ephemeral stream — A stream that flows in direct response to and only during and shortly after precipitation events. Their beds are always above the elevation of the water table, and stormwater runoff is their primary source of water. Ephemeral streams include normally dry arid or semi-arid region desert washes and arroyos. See *Episodic stream.*

Evaporitic crusts — Thin crusts of minerals (e.g., salts, carbonates, nitrates) that precipitate from water solutions as these solutions evaporate.

First- or Second-order Streams — Relative to stream order. The smallest and second smallest tributary to downstream watercourses. See *Stream Order.*

Fish and Wildlife — All wild animals, birds, plants, fish, amphibians, invertebrates, reptiles, and related ecological communities, including the habitat upon which they depend for continued viability (FGC Division 5, Chapter 1, section 45, and Division 2, Chapter 1, section 711.2(a), respectively). Fish means wild fish, mollusks, crustaceans, invertebrates, or amphibians, including any part, spawn or ova thereof (FGC, Division 5, Chapter 1, section 45).

Flood water — A body of water that overtops its natural or artificial confines and that covers land not normally under water; flows that escape from the usual channels under conditions that do not ordinarily occur.

Floodplain — A floodplain is a relatively flat area of land associated with a stream and over which water and sediment from a stream flows when the capacity of the channel is exceeded.

Floodplains parallel stream channels but may also occur at the terminal end of a stream where the channel joins an *axial valley stream*, transitions into a *playa*, or the channel ends and its stream flow disappears into the ground to join the groundwater of the area. Not every stream is associated with a floodplain, but where floodplains occur they are considered integral to stream function and to define the outermost bounds of a watercourse in cross section and length. Floodplains and their surfaces are defined by the lateral extent of water that overflows subordinate channels but that has not escaped the main watercourse.

Flow lineation — Linear grooves in a streambed or accumulations of materials (e.g., sand, pebbles) that are aligned in the direction of stream flow.

Fluvial — Of or pertaining to rivers and streams.

Geomorphic processes — The earth processes that influence the landscape and, in the case of streams, shape channel form through sediment movement, erosion, and deposition.

Geomorphologist — One who practices the interdisciplinary and systematic study of landforms and their landscapes as well as the earth surface processes that create and change them.

Geomorphology — The science that treats the general configuration of the Earth's surface; specifically the study of the classification, description, nature, origin, processes and development of present landforms and their relationships to underlying structures, and the history of geologic changes as recorded by these surface features. In the United States, it has come to replace the term "physiography" and is usually considered a branch of geology. In the British Commonwealth, Japan and many other countries, it is usually regarded as a branch of geography.

Granule — A rock fragment larger than a very coarse sand grain and smaller than a pebble, having a diameter in the range of 2-4 mm.

Gravel	Unconsolidated accumulation of typically rounded rock fragments consisting predominantly of particles larger than sand (>2 mm), such as granules, pebbles, cobbles, and boulders, or any combination.
Gravel bar	See *Bar* and *Bar Types*.
Gravel or Pebble ramp	A ramp-shaped deposit of gravel that accumulates on the upstream side of vegetation in or along a stream channel; an indicator or stream flow and sediment transport.
Headcut	An abrupt, vertical drop in the bed of a stream channel that is actively eroding upstream (or in a headward direction).
Headwater	The source or sources and upper part of a stream, including the upper drainage basin.
Holocene	The geological epoch that began at the end of the Pleistocene (around 12,000 to 11,500 years ago) and continues to the present.
Imbricated clasts	Overlapping clasts, as tiles on a roof or scales on a fish.
In-situ	In place.
Interfluve	Relatively undissected, fluvially inactive, upland or ridge between adjacent stream channels flowing in the same direction.
Intermittent stream	A stream that flows only at certain times of the year, as when it receives water from groundwater, or from surface sources like springs or snow-melt. Runoff from rainfall is a supplemental source of water for streamflow. See *Episodic stream.*
Island	Elevated body of land that is periodically surrounded by and isolated from the upland landscape by water. Islands are part of the watercourse unless their landscape and ecosystem characteristics differ from those of the watercourse, and there is minimal physical or biological exchange between them and the stream.
Levee (natural)	A long, broad, low ridge of gravel, sand, and silt deposited by a stream on its floodplain along the banks of the channel.
Low-flow channel	The topographically lowest stream channel or the dominant subchannel within a compound channel watercourse.
Meander, Meandering	The curve or winding of a stream channel in its alluvial valley.
Mid-channel bars	See *Bar* and *Bar Types*.
Mud cracks	An irregular fracture in a crudely polygonal pattern formed by the shrinkage of clay and silt, (or mud), during drying; also referred to as *shrinkage cracks* or *desiccation cracks*.
Mud drapes	A thin layer of clay and silt deposited on top of coarser sediment during waning stream flows.

Optically stimulated luminescence An optical dating method that relies on the assumption that the mineral grains were sufficiently exposed to sunlight before they were buried. Ages can be determined typically from 300 to 100,000 years before the present.

Ordinary High Water For the purposes of determining the Waters of the US (as administered by the US Army Corps of Engineers for purposes of compliance with Section 404 of the Clean Water Act), the term is defined as “that line on the shore established by the fluctuations of water and indicated by physical characteristics such as a clear, natural line impressed on the bank, shelving, changes in the character of soil, destruction of terrestrial vegetation, the presence of litter and debris, or other appropriate means that consider the characteristics of the surrounding areas.”

Out-of-channel flow Stream flow that exceeds channel capacity and overflows onto the floodplain areas that parallel a stream channel or occur at the terminal end of a stream channel. See *Floodplain*.

In low relief areas along the lower alluvial fan apron or alluvial plain where the capacity of individual channels is exceeded, out-of-channel flows may coalesce and spread out in a thin, relatively uniform expanse of shallow flooding that appears similar to *overland flow* and *sheetflooding* but is a distinct flood level that overflows onto the floodplain areas that define the outermost bounds of a watercourse in cross section and in length. Out-of-channel flows do not include extraordinary flood waters that have escaped from the watercourse to inundate lands not normally submerged, and that do not return to the watercourse.

Overland flow The down slope movement of water taking the form of a thin, continuous layer over relatively smooth soil or rock surfaces and not concentrated into channels larger than rills (i.e., very small, steep-sided channels resulting from erosion and cut in unconsolidated materials by concentrated but intermittent flow of water). This flow typically is short-lived with a limited travel distance; a relatively high-frequency, low-magnitude event. See *Sheet flow* and *Sheetflood.*

Pavement A closely packed stony surface generally composed of a layer of angular or subrounded gravels one or two stones thick sitting on a layer of finer stone-free, eolian-derived fine sediment. See also *desert pavement.*

Pebble A general term for a small, roundish stone; a rock fragment larger than a granule and smaller than a cobble, having a diameter in the range of 4-64 mm.

Percent Total Vegetative Cover As used here, a measure of the percent of ground covered by the crowns of all live perennial and shrub species within a sample area as viewed from above (see also *absolute cover*). Use the sample “Percent Landscape Cover Diagrams” attached to the data sheet to estimate total vegetative cover.

Perennial As used here, an herbaceous plant lacking woody tissue that lives for more than two years. The term is often used to differentiate a plant from shorter-lived annuals (a one-year life cycle) and biennials (a two-year life cycle).

Perennial stream	A stream that flows continuously during a year of normal rainfall; groundwater is the primary source of water for streamflow, and runoff from rainfall is a supplemental source.
Petrocalcic horizons and calcification	The accumulation of secondary calcium carbonate in the sediments, voids, or crevices within soils or bedrock below the surface in semiarid regions due to soil-forming processes or ground-water evaporation. The accumulation of calcium carbonate in arid and semiarid region soils is characterized by the following stages of development: **Stage I.** The carbonate accumulation consists of a horizon with a few filamentary deposits or thin coatings of carbonates. **Stage II.** Few to common carbonate nodules with K-fabric are formed; they may be soft or indurated. **Stage III.** Is characterized by numerous, commonly cemented or indurated carbonate nodules carbonate impregnation and cementation. At the end of stage III, the internodular matrix also is impregnated and plugged with carbonates; the horizon has then a continuous K-fabric and is cemented. **Stage IV.** A continuous, indurated calcic horizon that is cemented by calcium carbonate, and in some places, with magnesium carbonate, and includes deposition of one or more almost pure carbonate laminae on top of the cemented horizon.
Plant community	An assemblage of one to many plant species distinct in species composition or structure from other adjacent groupings or assemblages. Often influenced by a specific combination of environmental characteristics such as soil moisture, climate, and soil chemistry.
Playa and Playa lake	A playa is a dry, flat area at the lowest part of an undrained desert basin. It is largely free of vegetation and underlain by stratified clay, silt, or sand, and commonly by soluble salts. A playa lake is an intermittent lake in an arid or semiarid region, covering or occupying a playa in the wet season but subsequently drying up.
Pleistocene	The geologic time period (epoch) from 2,588,000 to 11,700 years before the present time.
Professional Geologist	California state law requires that studies of geological processes and/or materials that affect the public health, safety, welfare, or financial worth of a property be conducted by a licensed Professional Geologist with a college degree in the discipline, and expertise in work experience as demonstrated by passage of a State-administered qualifying examination. Business and Professions Code section 6700 et seq. (Professional Engineers Act) and/or section 7800 et seq. (Geologists and Geophysicists Act).
Protocols	Detailed study plans that provide the rationale and instructions for carrying out actions. Protocols consist of a narrative, standard operating procedures, and supplementary materials.

Quaternary The geologic time period from 2.588 million years ago to the present.

Radiocarbon dating (or simply carbon dating) is a dating technique that uses the decay of carbon-14 to estimate the age of organic materials, such as wood and leather, up to about 58,000 to 62,000 years.

Recurrence interval The average time interval between the occurrences of a hydrological event of a given or greater magnitude.

Relative cover A measure of the relative cover of a species in relation to that of other species within the sample area. Compare to *absolute cover*.

Relict landform
Relict channel A landform remnant that has survived after the processes responsible for its formation have ceased; a channel or remnant of a channel that is no longer part of an active fluvial process. Includes features of antiquity.

Ripples Relatively small bed forms that are exposed on bed surfaces of modern sediments and bedding plane surfaces of sedimentary rocks due to the interaction of a moving fluid (air or water) with a mobile substrate (mostly sand-size sediment).

Resiliency The capacity of an ecosystem to experience disturbance without losing its essential character and becoming something else; the capacity of a particular ecological attribute or process to recover to its former reference state or function after exposure to a temporary disturbance and/or stressor. The ability of a natural ecosystem to restore its structure following acute or chronic disturbance. Resilience is a dynamic property that varies in relation to environmental conditions.

River See *Stream*.

Rock varnish A dark coating from 2 to 500 microns thick that forms on rocks at and near the surface by precipitation of clay and iron and/or manganese oxides forming red and black varnishes, respectively. The thickness or the coating increases with time if abrasion or burial of the rock surface do not occur. As a result, clasts on alluvial fan surfaces that have been inactive for long periods of time have darker and thicker coatings of varnish than younger surfaces.

Rubification A soil development in which iron is released from primary minerals to form free iron oxides that coat rocks or particles in soils with a thin reddish film.

Runoff The part of precipitation appearing as surface flow in streams.

Average rates of surface water generating runoff in the Mojave Desert have been estimated to have a recurrence interval of 2.6 to 7.3 years (Griffiths et al. 2006)

Sand A detrital rock fragment or mineral particle smaller than a granule and larger than a coarse silt grain, having a diameter in the range of 0.0625 to 2 mm.

Secondary channel	Topographically higher channels within a watercourse that carry water only during higher flows. Also known as overflow or high-flow channels.
Scour	The concentrated clearing and digging action of flowing water that removes sediment from a streambed; the process of erosion that is controlled by the velocity of water flowing in a channel.
Sediment	Loose, unconsolidated fragmental material that originates from weathering of rocks and is transported or deposited by air or water, ice, or as precipitation from solution (salts, calcium carbonate); e.g. sand, gravel, silt, mud, alluvium; the alluvial material (e.g., silt, sand, gravel) carried by a stream.
Sediment plastering	Sand and gravel deposits adhered to stream banks by passing flows; distinct from the stream bank deposit itself, and indicative of more recent sediment transport.
Sediment ramps	A ramp-shaped deposit of gravel or sand that accumulates on the upstream side of vegetation or boulders in or along a stream channel; an indicator or stream flow and sediment transport.
Sheetflood	A broad expanse of moving, storm-borne water that spreads as a thin, continuous, relatively uniform layer over a large area in an arid region and that is not confined to well-defined channels; its distance of flow is short and its duration is measured in minutes or hours. Sheetfloods usually occur before runoff is sufficient to promote channel flow, or after a period of sudden and heavy rainfall. See *Out-of-channel flow.*
Sheet flow or Sheetwash	The down slope movement of water taking the form of a thin, continuous layer over relatively smooth soil or rock surfaces and not concentrated into channels larger than rills (i.e., very small, steep-sided channels resulting from erosion and cut in unconsolidated materials by concentrated but intermittent flow of water). This flow typically is short-lived with a limited travel distance; a relatively high-frequency, low-magnitude event. See *Overland Flow.*
Shrub	A woody species that generally has two to several stems from the base, giving it a broad crown, and is usually less than 5 meters in height.
Silt	A sediment particle smaller than a very fine sand grain and larger than coarse clay, having a diameter in the range of 0.004 to 0.0625 mm.
Single-thread channel	A stream where flow is restricted to a single, discrete channel.
Splay deposits	A low energy, deltaic deposit, oriented perpendicular to a main channel, formed by a break in a natural levee during flood stage.
Soil	Unconsolidated mineral or organic material on the surface of the earth that has been subjected to and shows effects genetic and environmental factors of: climate (water and temperature effects, micro- and macro-organisms, conditioned by relief, and acting on the parent material over time. Soil development begins when the surface of a deposit is stabilized, is no longer episodically buried by fluvial or eolian depositional processes, and is undergoing little erosion.

Soil Crusts See *Algal crusts* and *Biotic soil crusts*.

Stream A body of flowing water and the landform that conveys it, including water sources and adjoining landscape elements that are byproducts of and affected by interactions with flowing water without regard to size, duration, or the timing of flow.

Stream order A measure of the position of a stream (defined as the reach between successive tributaries) within the hierarchy of the *drainage network*. First-order streams have unbranched tributaries; a second-order stream is a stream after the junction of the first tributary, and so on.

Surface rounding The subdued, rounded landscape that is developed over time by wind and surface runoff in the absence of fluvial activity. Generally indicates an old landform.

Suspended sediment The total stream sediment load that is carried in suspension above the stream bed, consisting mainly of clay, silt and fine sand.

Swale Depression or hollow where runoff from the surrounding uplands accumulates. Swales that yield channel flow are important sources of water, sediment, nutrients, and other materials during runoff, and are considered source areas to and integral parts of streams.

Terrestrial processes Upland processes dominated by non-fluvial, landscape-shaping mechanisms of wind, surface runoff, weathering, and soil development. *See Upland.*

Terrace One of a series of level surfaces in a stream valley, flanking and paralleling the stream channel, originally occurring at or below, but now above the level of the stream, and representing the dissected remnants of an abandoned floodplain, stream bed, or valley floor produced during a former (and higher) stage of erosion or deposition.

Tertiary The geologic time period from 65 million to 1.806 million years ago.

Transmission losses The water loss due to seepage of surface flow into the unconsolidated sediment of the channel bed and banks.

Uplands The higher ground dominated by terrestrial – or non-fluvial – processes that is above a watercourse and the high water level of a stream.

Vesicular A horizon See *Av horizon.*

Wash A broad, shallow, sandy or gravelly, and normally dry bed of an intermittent or ephemeral stream. See S*tream*.

Watercourse

The course over which water currently flows, or has flowed as defined by the topography that confines the water to this course when the water rises to its highest level.

A *stream* may have more than one active channel or, as is more often the case, secondary channels that receive water only during higher flow events. Where present*, low flow channels, active channels, banks* associated with these channels, *floodplains*, and stream-associated vegetation, all lie within the bounds of a single larger channel, designated the watercourse channel to discriminate between it and similar but smaller secondary features that lie within its bounds.

Watershed

An area of land that drains water, sediment, and dissolved materials to a common outlet.

Wrack

A waterborne deposit mainly of sand, gravel, organic detritus and other debris; a linear deposit along the banks of a stream, and less organized where the deposit is precipitated by its capture by complex vegetation or rock.

Wrinkle marks

Small, discontinuous, more or less parallel ridges and hollows. Orderliness of the pattern varies from poor to good, giving the appearance of small, linear ripple marks; formed in loose, fine grained sand deposits on high point bars and longitudinal bars, and on floodplains.

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